TF1807

NORTH ATLANTIC
industries, inc.

OPERATING AND INSTRUCTION

MANUAL FOR

MODEL 301 BROADBAND

PHASE ANGLE VOLTMETER

S-579

Patents are Pending for a Number of Circuits

Used in This Instrument

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

Copyright 1962, 1963 by North Atlantic Industries, Inc.
Printed in U.S.A.

Digitized by the Internet Archive
in 2025

https://archive.org/details/manualsplus_09992

TABLE OF CONTENTS

PAGE

SECTION ONE

General Description

Introduction..... 1.1
Applications..... 1.1
Accessories..... 1.2
Specifications..... 1.4

SECTION TWO

Operating Instructions

Removal from Package..... 2.1
Power Line Voltage and Cable..... 2.1
Controls, Displays, Inputs..... 2.2
Operation..... 2.6
Filter Operation..... 2.11

SECTION THREE

Theory of Operation

Signal Channel..... 3.1
Reference Channel..... 3.4

SECTION FOUR

Maintenance

Cover Removal..... 4.1
Replacement Of Parts..... 4.2
Replacement Parts List..... 4.4

SECTION FIVE

Checkout and Alignment Procedure

Initial Ground Check..... 5.1
Initial Power Supply Voltage Check..... 5.1
Voltage Range Adjustment..... 5.3
Reference Pre-Amp Adjustment..... 5.3

(Continued)

TABLE OF CONTENTS

(Continued)

Reference Channel Sensitivity..... 5.4
Common Mode Adjustment..... 5.4
ZERO Switch Adjustment..... 5.5
High Signal Range Adjustment..... 5.10
Overload Adjustment..... 5.11
Phase Network Alignment..... 5.12
Phase Potentiometer Trimming..... 5.14

LIST OF ILLUSTRATIONS

Figure 2.2 - 90° Signal Amplitude Characteristic..... 2.11
Figure 2.3 - Typical Filter Curve..... 2.13
Figure 3.1 - Functional Schematic..... 3.2
Figure 3.2 - Sig Pre-Amp..... 3.3
Figure 3.3 - Signal Amplifier..... 3.5
Figure 3.4 - Ref Pre-Amp..... 3.6
Figure 3.5 - Reference Amplifier..... 3.8
Figure 3.6 - Phase Network and Modules..... 3.9
Figure 3.7 - Zero Phase..... 3.11
Figure 3.8 - 90° Signal Amplitude Characteristics..... 3.13
Figure 3.9 - Monitor Voltmeter..... 3.14
Figure 3.10 - Reference Drive Amplifier..... 3.15
Figure 3.11 - Power Supply..... 3.19
Figure 4.1 - Sig Pre-Amp..... 4.5
Figure 4.2 - Signal Amplfier Board Assembly.... 4.10
Figure 4.3 - Ref Pre Amp..... 4.13
Figure 4.4 - Ref Amplifier Assembly..... 4.16
Figure 4.5 - Zero Phase..... 4.18
Figure 4.6 - Monitor Voltmeter..... 4.25
Figure 4.7 - Reference Drive Amplifier..... 4.29
Figure 4.8 - Power Supply Terminal Board..... 4.33
Figure 4.9 - Meter Board Assembly..... 4.35
Figure 4.10 - Sig De-Coupling..... 4.37
Figure 4.11 - Signal Filter and Overload Assembly..... 4.39

LIST OF ILLUSTRATIONS

(Continued)

Figure 5.1 - Top View..... 5.7
Figure 5.2 - Bottom View..... 5.8

SECTION I

GENERAL DESCRIPTION

Introduction

The Model VM-301 Broadband Phase Angle Voltmeter, shown in the photograph of Figure 1.1, combines in one instrument the ability to measure both phase angle and magnitude of complex AC signals and their vector components with respect to a reference voltage. Designed to operate over the frequency range from 10~ to 100KC, it utilizes passive phase shifter circuits (patents applied for) to assure high accuracy over this spectrum. Because of these broadband characteristics, the Model VM-301 fills a long existing need for a null and phase meter in which the signal frequency may vary. Measurements of AC ratios, phase angles, and related quantities may be made with non-stable frequency sources, or while sweeping frequency to determine phase versus frequency characteristics.

Front panel controls permit instantaneous selection of range, function and frequency band. As a phase sensitive null meter, the instruments' 2 microvolt sensitivity permits high resolution ratiometric measurements. This requires measurement of low level voltages of the reference frequency in the presence of noise, hum, and other spurious signals. As a phase meter, angles are read on a high resolution, parallax-free scale, calibrated in 0.2^{o} increments. Two simple push and set controls permit trimming to the existing source frequency to achieve best absolute accuracy. Plug-in, interchangeable, harmonic filters are available and can be simply installed or removed from the front of the instrument without disassembly.

High input impedance signal and reference channels minimize errors due to loading and common ground signals. Reference levels may be anywhere in the range of 150MV to 300V. Successful measurements can be made with reference levels less than half of the lower value or 75MV.

Applications

A. Phase Sensitive Null Indicator.
B. Measures separately the in-phase and quadrature components of an AC signal.
C. Measures phase shift in any AC system.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

D. Sensitive AC vacuum tube voltmeter.
E. Testing of Servos, Computers, Synchros, Resolvers, Inductosyns.
F. Precise AC Ratiometry.
G. Phasing of Servo Motors, Chopper Amplifier, Magnetic Amplifiers.
H. Measuring both torque and non-torque producing signals in servo amplifiers.
I. Align carrier amplifier and notch networks.
J. Impedance meter.
K. Power factor meter.
L. Measuring response of vibrational system.

Detailed descriptions of these applications are shown in the Application Notes appended hereto.

Accessories

Filters

Filters of the low pass plug-in type can be supplied in the range of 50~ to 100KC for harmonic rejection in both signal and reference channels. Special band pass filters are available for these and higher frequencies, if necessary. These filters may be plugged into the unit and switched in and out of circuit from the front with no disassembly.

P-201 Reference Isolation Module

This plug-in module is intended for applications which require that the external reference signal generator be isolated from the Reference and/or Signal Channels of the measuring instrument. It will eliminate errors due to extraneous currents in the signal circuits from common ground connections. The module plugs directly into the banana jacks of the reference input on the North Atlantic Phase Angle Voltmeter.

P-203 Universal Isolation Module

This module is a plug-in transformer module designed for precision bridging and signal or reference isolation

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

application in phase sensitive AC voltage measurements and AC ratiometry. The unique shielding design incorporates special separate shielding of the primary and secondary windings. It can be used as a precision bridging transformer for establishing null voltages in critical AC measurements. Used as a signal isolation transformer, it allows the signal source to be isolated from the measurement instrument and power ground without detriment to the measurement accuracy. This design provides absolute minimum coupling of the primary common-mode signal into the secondary winding.

NOTE:

THE PROPER APPLICATION OF THESE MODULES EXTENDS THE VERSATILITY OF AC PHASE DETECTION AND RATIOMETRIC INSTRUMENTS TO A WIDE RANGE OF MEASUREMENT TESKS IN ACTUAL SYSTEMS WHERE GROUND LOOPS AND EXACT MEASUREMENT CONDITIONS CANNOT BE DEFINED OR PREDICTED IN ADVANCE. THESE PRECISION MODULES ARE DESIGNED TO BE UNIVERSALLY USED WITH ANY AC RATIOMETRIC AND PHASE DETECTION INSTRUMENTS PROVIDED WITH STANDARD 3/4" SPACED BANANA JACKS, SUBJECT TO FREQUENCY RESPONSE.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

Specifications

A. Electrical

Voltage Range:

Full scale 1MV to 300V in 12 ranges.
Full scale -60db to +50db in 12 ranges.

Frequency Range:

Filter Out:
VTVM: 10 cps to 100KC
Phase Sensitive: 10~ to 100KC (selected in half-decade steps by front panel control).

Filter In:
VTVM and Phase Sensitive: Any frequency within band of 10~ to 100KC determined by plug-in filters.

Voltage Accuracy:

Voltage ±2% full scale over full Frequency Range.

Calibration:

Meter: Zero center mirror scale, 3-0-3 and 10-0-10 scales, plus log scale calibration in db (-14 to ±2db).

Phase Angle: 0^{o} - 90^{o} calibrated Phase Dial with 0.2^{o} magnified divisions. Dial has 2^{o} overlap into adjacent quadrants. Four positions quadrant selector covers 0-360^{o} non-ambiguously.

Phase Accuracy:

Using calibrated Phase Dial:

1. ±0.25^{o} from 31.6 cps to 31.6KC.
2. 31.6KC to 100KC: Gradual degradation as frequency is increase to ±1^{o} @ 100KC.
3. 10~ to 31.6~: Gradual degradation as frequency is increased to ±0.6^{o} @ 10~.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

	Using E cos θ characteristic: ±3% full scale angle.
Sweep Frequency Capability:	(See Text, Section II, "Sweep Frequency Measurement," for discussion) Phase Dial at Cardinal Angles: 2^{o} nominal from 10 cps to 31.6KC 7^{o} nominal from 31.6KC to 100KC (Zero and Euqal control set arbitrarily).
	Phase Dial at 45^{o}: 2.5^{o} nominal (Equal control set at approximately 84% or 36% top frequency in half decade).
Phase Resolution:	0.03^{o} at 10X overload (1/4 Div.)
Input Impedance:	Signal: 10 Megohms, 47uuf, nominal, all ranges.
	Reference: 10 Megohms, 47uuf, nominal.
Reference Level:	Variable from 0.15 to 130V by Hi-Lo Selector plus vernier.
Input D.C. Voltage Level:	D.C. levels may be applied without affecting performance such that the peak value of the combined A.C. and D.C. voltages shall not exceed 1000V in the signal and reference input.
Overload:	Overload lamp lights at input 10X full scale setting.
Noise (VTVM):	Less than 10 microvolts in "Filter Out." Less than 20 microvolts in "Filter In."
Nulling Sensitivity: (Phase Sensitive)	Less than 2 microvolts in phase sensitive mode.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

Harmonic Rejection:	Low pass sharp cut-off plug-in filters (50~ to 10KC range) rejection of 30db outside pass band. By proper choice of filter this may be increased to 50db for any specific frequency. In addition, detector characteristics reject all even order harmonics by greater than 55db as well as odd order harmonics in inverse proportion to the harmonic order.
Non-Coherent Signal Rejection:	For frequencies removed from signal frequency by approximately 5 cps or more (effective pass band of meter movement) response is essentially nil for levels up to 10 times the value of the full scale in use. Appropriate filters can increase the allowable level of the non-coherent signal to 300 times the value of the full scale in use on the most sensitive scales.
Power:	115/220 volts ±10%, 50 to 400 cps, 80 watts. Fused @ 2 amp for 115V operation.

B. Mechanical

Size:	Panel: 7" x 19" x 1/8" with standard rack mount slots. Depth Behind Panel: 11 3/4"
Weight:	32 lbs. approximately
Mounting:	Unit is supplied with chrome plated end bells, with recessible feet, for bench use. These can be removed for rack mounted applications.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

Front Panel Paint:	Gray #26440 per Fed. Std. 595
Front Panel Marking:	Black #37038 per Fed. Std. 595
Front Panel Bezels:	Black #37038 per Fed. Std. 595
Power Cord:	6' long minimum
Front Panel:	Inputs are standard five-way binding posts spaced on 3/4" centers. Ground terminals are colored Black and marked "GND." High side of inputs are Red Terminals. Chrome terminal represents chassis ground.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

SECTION II

OPERATING INSTRUCTIONS

Removal from Package

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging material used in the container to ensure that no damage result from the typical handling encountered during shipment. However, upon removal from package, the instrument should be externally inspected for any obvious damage. Should such be observed, refer to Warranty Policy previously presented.

Prior to making any connection, check meter to see that it reads zero. If it does not, reset the meter to read zero by means of the adjusting screw near the bottom in the rear of the meter. A hole is provided in the shield covering the meter terminals for this purpose. To accomplish this, turn thumb screw directly below the meter, 1/4 turn counterclockwise, pull meter drawer chassis forward. This adjustment must be done with the power off a and with the instrument in a horizontal or near horizontal position.

This instrument is provided with side pieces, which, when removed converts it from a bench to a rack-mounted. These end pieces contain swivel front legs to improve reading angle.

Power Line Voltage and Cable

The instrument is normally wired for 115 volt operation. If it is desired to operate the instrument from a 230 volts source, refer to the transformer conversion data on Figure 2.1 for the correct procedure. TB4 is located underneath the power transformer on the back panel.

Use the proper fuse in each position.

115 V Source - 2 Amp Fuse
230 V Source - 1 Amp Fuse

All electrical circuit and power grounds are floating with respect to chassis. The instrument is supplied with a three prong power plug, the round pin is wired to the chassis. Common grounding of power, chassis, and circuit ground is accomplished by means of a link on the signal input terminals. The circuit ground must be connected to chassis ground either at the input terminals or remotely. Dependent upon specific applications, it may be more

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

desirable to wire the chassis such that it is not connected directly to house ground.

In those cases, extreme caution must be taken to avoid any personal injuries due to the resultant shock hazard. As a general rule, every effort must be made to ensure that the chassis is wired to a house ground at all times.

Controls, Displays, Inputs

Prior to attempting to operate this instrument, it is advisable that the user familiarize himself with every control, display and input connection as described below.

On-Off Switch

A toggle switch which energizes the primary circuit of the power transformer. With the switch "ON" the meter face will be illuminated.

Range Switch

A rotary switch which selects the proper multipliers for the desired voltage range. The Range Switch indicates both the full scale voltage and the db level at each position. The zero db point is equivalent to 1 millivolt in 600 ohms.

Function Selector

The "Function Selector" selects the desired mode of operation for the instrument. In the four Phase Angle Voltmeter positions, the instrument is connected so that it may read a voltage E cos α where α is defined as the angle by which the signal vector leads the reference vector. The "Function Selector" selects the quadrant over which the calibrated phase shifter will operate. Thus, the total angle shifted in degrees will be either 0°, 90°, 180°, or 270°, plus the reading of the Phase Dial.

In the "VTVM" position, the instrument functions as a standard voltmeter. With the Filter Switch in the

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

"Filter In" position the instrument will read the total vector voltage of the fundamental signal.

Frequency Selector

This dual concentric switch selects the desired frequency range in half-decade steps. The entire frequency band is divided into two spectrums, 10~ to 1KC and from 1KC to 100KC. The large drum dial selects either the high or low spectrum. The small pointer knob then selects the proper half-decade step within the spectrum.

Filter Selector

This inserts the harmonic attenuation filters either into or out of the signal and reference channel simultaneously.

Reference Level Switch and Control

This switch and the associated potentiometer represents the Reference Channel Range Selector, allowing the wide range of reference (.15V to 130V) to be used. This is not a calibrated control and for proper adjustment of the Reference Hi-Lo and Level Control, see the Reference Level Meter, description in this section.

Zero Switch, Equal Switch, and Controls

Combined, these controls perform the necessary trimming of the two Amplifier Channels and Phase Shifter Networks to align the instrument for most accurate phase measurements at a specific frequency.

Filter Amplitude Adjustment

This control is mounted on the right side of the slide draw behind the voltmeter and is used when changing filters to compensate for the difference in insertion loss associated with the filters. Information regarding its use is presented in the section describing Filter Operation.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

Voltmeter

The meter is a zero center D.C. milliameter calibrated to read the RMS value of a sine wave. For "STD VTVM" reading, the needle deflects to the right. For "Phase Angle VTVM" reading, the meter deflection may be to the left or right. It has calibrated zero center 3-0-3 and 10-0-10 scales, plus a log scale calibrated in db.

CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE MAY OCCUR IF THE SIGNALS ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

Reference Level Meter

This zero suppressed meter indicates the reference voltage level within the phase shift networks. This is used for phase reference level adjustments and phase network trimming purposes. Its use is described in the section dealing with Reference Level Adjustment.

Phase Dial

A dial which is calibrated to read the degrees of Phase Shift introduced by the calibrated phase shifter network within the particular quadrant selected by the "Function Selector." The dial is calibrated -2^{o} to $+92^{o}$ in 0.2^{o} graduations. Mechanical positioning of this dial, on its shaft, is critical and for this reason should it be necessary to repair or replace, the procedure under "Phase Dial Alignment" should be followed.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

Overload Indicator

The lamp marked "Overload" lights whenever a prescribed signal level is exceeded. As the signal reaches the overload condition, the lamp will blink. A steady glow indicates a large overload condition. This indication warns of impending amplifier overload and the attendatn inaccuracies which will occur when large saturating signals are present. The overload indicator is factory set to blink at ten (10) times full scale.

Input Terminals

Five terminals are provided at the front panel for connection to external test circuits. Terminals for both the signal and reference inputs are colored Black for circuit ground and colored Red for the high side of the input. These posts which are on a standard 3/4" spacing will accommodate banana plugs, wire, or alligator clips.

CAUTION: MAXIMUM SIGNAL INPUT MUST NOT EXCEED 1,000 VOLTS AND MAXIMUM INPUT REFERENCE MUST NOT EXCEED 600 VOLTS (COMBINED PEAK AC & DC LEVELS).

HIGHER VOLTAGES WILL BREAK DOWN THE INPUT CAPACITORS IN THE INSTRUMENT.

A third terminal is provided on the signal input for connecting circuit ground to chassis ground. As the voltmeter circuit grounds are floated above chassis, a link is provided between the metal terminal and the ground (Black) terminal of the signal input to allow maximum flexibility of connections. Great care should be given to grounding methods used to avoid ground loops and stray fields. The instrument will not read properly if the input is not grounded. The link is provided to permit grounding to a remote point in measuring set-up.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

Filters

Harmonic attenuation filters can be supplied in single frequency pairs for a specified band of frequencies in the range from 50~ to 10KC. These are plug-in units located behind the voltmeter and are accessible by rotating the thumb screw below the meter, 1/4 turn counterclockwise, and pulling the meter drawer assembly forward. More information is presented later under "Filter Operation."

Fuse

The Fuseholder mounted on the back of the instrument will accept either a 2 amp or 1 amp fuse, depending upon the line voltage as previously described.

Operation

Plug the instrument into the proper power source, turn the Toggle Switch to "ON." Allow the instrument to warm up about 15 minutes for stable operation. For precision phase measurements, additional time should be allowed.

CAUTION: BEFORE MAKING PHASE OR VOLTAGE MEASUREMENTS, REVIEW SECTION ON GROUNDING TECHNIQUES IN APPLICATION NOTES.

To Measure Voltage

Set the Range Switch to the appropriate scale and the Function Selector to the "VTVM" position. Connect the voltage to be measured to the signal input terminals. Read the voltage from either the 0-10 volt, 0-3 volt, or db scales, using the proper scale factor as determined by the range selector position.

With the Function Selector in the "VTVM" position and the Filter Switch in the "OUT" position, the voltmeter operates

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

as a standard AC VTVM. This AC VTVM reads the total vector voltage at any frequency including all harmonic effects. With the Filter Switch in the "IN" position and with the proper filters plugged into the instrument, the voltmeter will read only the fundamental voltage within the range of the filter.

Notice that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to effectively zero.

Switching the instrument into the "VTVM" position will cause the Reference Level meter to read off scale to the left. This is normal as the reference is disconnected internally in the "VTVM" position.

Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup. Twisted and/or shielded cable will reduce the effect although the cable capacity could serve to load the source.

Care must also be taken to ensure that ground loops do not exist by virtue of the signal and reference grounds being connected. These "loops" will result in erroneous readings.

Precise Phase Angle Measurements - Preliminary Adjustments

1. Set the Frequency Selector to the proper band for the frequency to be measured.

2. Switch Function Selector to a phase sensitive position.

3. Connect the reference voltage to the REF input terminals of the instrument. With the reference "HI-LO" switch and reference level control, adjust the reference input to give an ON scale reading on the reference level meter.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

(No particular setting is required, as the instrument will operate over a wide range of reference level. As long as an ON scale reading is maintained, the instrument will remain within calibration tolerances).

4. Depress "EQUAL" switch and note if there is any change in reference level meter from that observed in Step 3.

5. With "EQUAL" adjust knob, re-adjust reference meter to original reading. Adjust this control until there is no change in reference level when "EQUAL" switch is depressed or released.

6. Depress "ZERO" switch and, using the ZERO adjust knob, adjust Phase Angle Voltmeter to read exactly zero. Release "ZERO" switch, and proceed with measurements.

NOTE: The above steps have aligned the Phase Angle Voltmeter for accurate measurements at a particular frequency. Maximum accuracy may be had at any frequency in the spectrum of 10~ to 100 KC by following this procedure. The "EQUAL" procedure outlined in Steps 4 and 5 need only be done if the phase dial is set to other than "0°" or "90°." (See Theory of Operation.)

Phase Angle Measurements - With Calibrated Phase Shifter

1. Adjust Reference Channel as described above.

2. Switch the Range switch to a suitable position.

3. Switch the Function Selector to a suitable Phase Angle Voltmeter position and turn the degrees dial to read a near maximum.

4. Switch the Function Selector 90° from that in Step 3. Turn the degrees dial until the meter reads zero. Switch the Range Switch two ranges more sensitive. (e.g., If Step 3 is performed on the 100MV range, then this should be done on the 10MV position.)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

Adjust the Phase Dial more precisely for a null on the meter. Switch the "Function Selector" to a position (0°, 90°, 180°, or 270°) which gives a meter deflection to the right. The phase angle is then the sum of the Function Selector angle plus the Phase Dial angle. This rule eliminates the possibility of ambiguity.

NOTE: IT IS VERY IMPORTANT TO SET THE EQUAL CONTROL WHEN USING THE CALIBRATED PHASE DIAL, AS DESCRIBED IN STEP 1.

Phase Angle Measurements with In-Phase & Quadrature Components

Accurate measurement of phase angle can also be made using the E cosine α or E sine α characteristic. Voltage measurements are made of the in-phase or quadrature component and of the fundamental signal (STD VTVM position). The quotient will then be the cosine, or sine, or tangent of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure, and for that reason, it is suggested the Application Notes be reviewed before using this method.

1. With reference channel adjusted as described in "Phase Angle Measurements - Preliminary Adjustment," place Function Selector in 0° position. Set the Phase Dial at 0°.

2. The meter now reads the in-phase component of a signal. This is also E cosine α where α is the angle between the reference and signal.

3. Switch the Function Selector to 90°. The meter now reads the quadrature component of the signal which is E sine α. In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the overload lamp lights, thereby warning of an impending overload condition.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

This light indicates that the total signal exceeds 10 times the full scale value.

Sweep Frequency Measurements

If it is desired to make less accurate phase measurements while sweeping frequencies, it is possible to accomplish this without adjustment of the "EQUAL" or "ZERO" controls. To do this, it is necessary to understand the two sources of error inherent in this procedure.

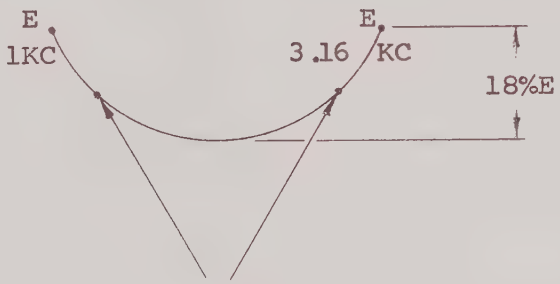
The first is the phase misalignment between the reference and signal channels that occurs as the frequency is varied. This is generally small within each half decade but can increase to a few degrees as the frequency is varied from decade to decade. This error will affect accuracy at all angles of the Phase Dial. If it is desired to minimize this error, an adjustment of the "ZERO" control in the middle of each half decade band can be made.

The second source of error is due to the difference in the amplitude gradients of the internally generated 90° and 0° signals applied to the phase bridge. (See Theory of Operation). The 0° signal is relatively constant with frequency, but the 90° signal varies in an identical parabolic manner from half decade to half decade. This voltage is a maximum at the two extremes of the half decade, dipping in the middle of the band to a value 18% below the value at the extremes. This pattern is repeated in every half decade. This parbolic curve is shown below for the 1KC - 3.16KC band. The function of the "EQUAL" control is to adjust the 0° and 90° voltages to equal amplitude. The error due to these two voltages not being equal is maximum at 45° of the Phase Dial (0.28°/% difference in amplitude) and has no effect at the 0° or 90° position of the Phase Dial. Since this pattern is repeated from half decade to half decade, it is possible to adjust the "EQUAL" control at one point in a half decade in such a way that the variation of the 90° signal amplitude is ±9% (See Figure 2.2) from this value and this pattern will

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

be repeated in every other half decade. The frequency to make this adjustment is approximately .84 or .36 of the maximum frequency of the half decade. This will limit the maximum error to ±2.5° at the 45° position of the Phase Dial. The error will be less at other positions of the Phase Dial.

90° Signal Amplitude Characteristics



Adjust "EQUAL" control here.

Figure 2.2

Filter Operation

General

Due to the potential errors in making phase measurements on signals containing significant harmonics, it is usually necessary to use harmonic filters to achieve the ultimate accuracy of this measurement. It is also sometimes desirable to make non-phase sensitive measurements on input signals. after removing noise and harmonic components. Therefore, provision is made for switching filters into both channels using the Filter "In-Out" switch while making both phase sensitive and non-phase sensitive measurements.

The filters used are plug-in, low pass types with a characteristic described by Figure 2.3. The filters are operated is a restricted portion of the pass band in order to maintain, over this band, the amplitude

gradient within the instrument specification and to restrict the phase variation. It will then be possible (at any frequency within the band) to make adjustments in the Filter "Out" position and switch to the Filter "In" position without having to make any further adjustment. Usable band limits were determined as follows:

f_m designates the geometric mean frequency of the usable band. Table 2.1 describes all filters available and their usable bands and Figure 2.3 is the typical filter response.

Upper frequency limit is determined by the amplitude vs. frequency characteristic. Lower frequency limit is determined by the amount of rejection of the third harmonic of this frequency.

Bands designated f_a ($.87f_m$ - $1.15f_m$) will have an amplitude variation of 1% over the frequency band and 30 db* rejection of the third harmonic of $.45f_o$. (f_o is the frequency where the amplitude is down 6 db* from the low frequency amplitude. See Figure 4.1).

Bands designated by f_p ($.78f_m$ - $1.25f_m$) will have an amplitude variation of 2% over the frequency band and 20db* rejection of the third harmonic of the lowest frequency.

*NOTE: When making phase sensitive measurements, the detector circuit inherently has high second harmonic rejection (approximately 55 db) and 10 db additional rejection of the third harmonic.

This additional harmonic rejection is, therefore, added to the filter rejection when operating in any phase sensitive mode.

It is possible to extend the range of any filter if additional attenuation is desired. If this is done, the filter adjustments described below must be made at each frequency used, and the usable band width around this frequency is severely limited. It is not recommended that a frequency of $1.62f_m$ be exceeded.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

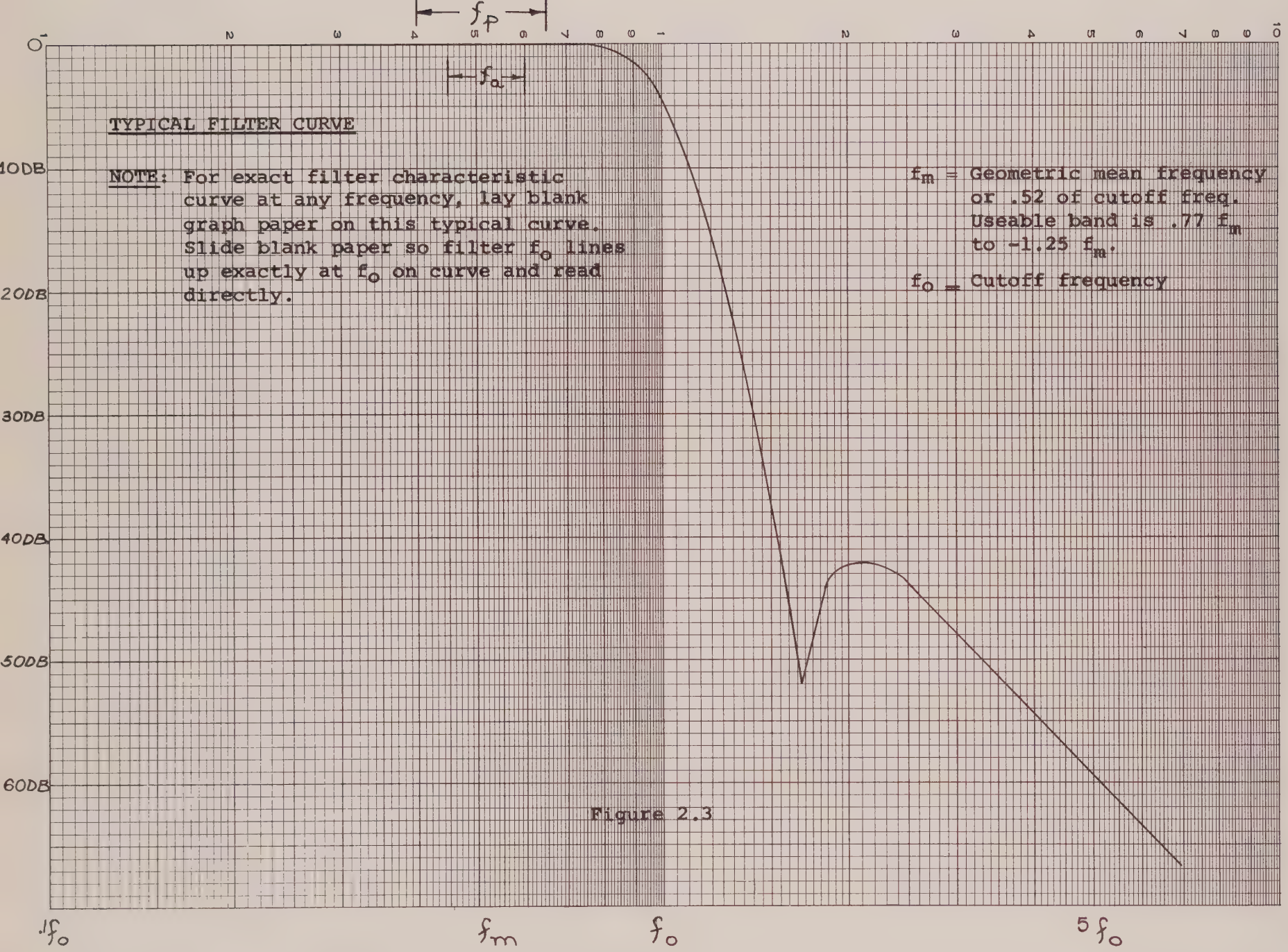

f_p
f_a
TYPICAL FILTER CURVE
NOTE: For exact filter characteristic curve at any frequency, lay blank graph paper on this typical curve. Slide blank paper so filter f_o lines up exactly at f_o on curve and read directly.
f_m = Geometric mean frequency or .52 of cutoff freq. Useable band is .77 f_m to -1.25 f_m.
f_o = Cutoff frequency
0
10DB
20DB
30DB
40DB
50DB
60DB
.1f_o
f_m
f_o
5f_o

Figure 2.3

CHART OF STANDARD FILTERS FOR VM-301

TABLE 2.1

PART NO.	fm	f_a (.87f_m-1.15f_m)	f_p (.78f_m-1.25f_m)
782081-2	52.0	45 to 60	40 to 65
782081-3	62.5	54 to 72	48 to 78*
782081-4	83	72 to 96	64 to 104
782081-5	104	90 to 120	82 to 130*
782081-6	130	113 to 150	101 to 162
782081-7	156	136 to 180	122 to 195*
782081-8	260	225 to 300	200 to 325
782081-9	208	180 to 240	162 to 260
782081-10	416	360 to 480	325 to 520
782081-11	520	450 to 600	400 to 650*
782081-12	346	300 to 399	270 to 432*
782081-13	780	680 to 900	620 to 975*
782081-14	675	585 to 780	520 to 845
782081-15	1.04KC	900 to 1200	820 to 1300
782081-16	1.56KC	1360 to 1800	1220 to 1950
782081-17	2.08KC	1800 to 2400	1620 to 2600
782081-18	2.6KC	2260 to 3000	2050 to 3250
782081-19	1.3KC	1125 to 1500	1015 to 1620*
782081-20	3.12KC	2725 to 3575	2430 to 3900*
782081-21	5.2KC	4500 to 6000	4000 to 6500*
782081-22	4.15KC	3600 to 4750	3240 to 5200
782081-23	6.11KC	5300 to 7000	4750 to 7600
782081-25	7.8KC	6800 to 9000	6200 to 9750*
782081-26	9.53KC	8250 to 11000	7400 to 11915

* This indicates filters which may be omitted when using f_p accuracy and still have complete frequency coverage.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Filter Adjustment

Pull out meter drawer and insert desired filters into octal sockets.

Amplitude Adjustment

a. Put in any convenient level of input signal at the f_m frequency of the filter.

b. Place Function Switch in "VTVM" position.

c. Turn Filter In-Out Switch to "OUT" position.

d. Turn Range Switch to range corresponding to ON scale reading with signal input available.

e. Observe reading on meter. This should be as close to full scale as possible.

f. Switch to Filter -In position and adjust R105 Filter Level Adjustment for the identical reading observed in Step "d." This control is mounted on the right side of the slide drawer behind the voltmeter.

g. No further adjustment need be made in R-105.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

SECTION III

THEORY OF OPERATION

The Functional Schematic of Figure 3.1 will serve to illustrate the prinicple of operation of the Phase Angle Voltmeter in its entirety. Note that detailed schematics showing all components are also included as Figures 3.2 through 3.11.

Signal Channel

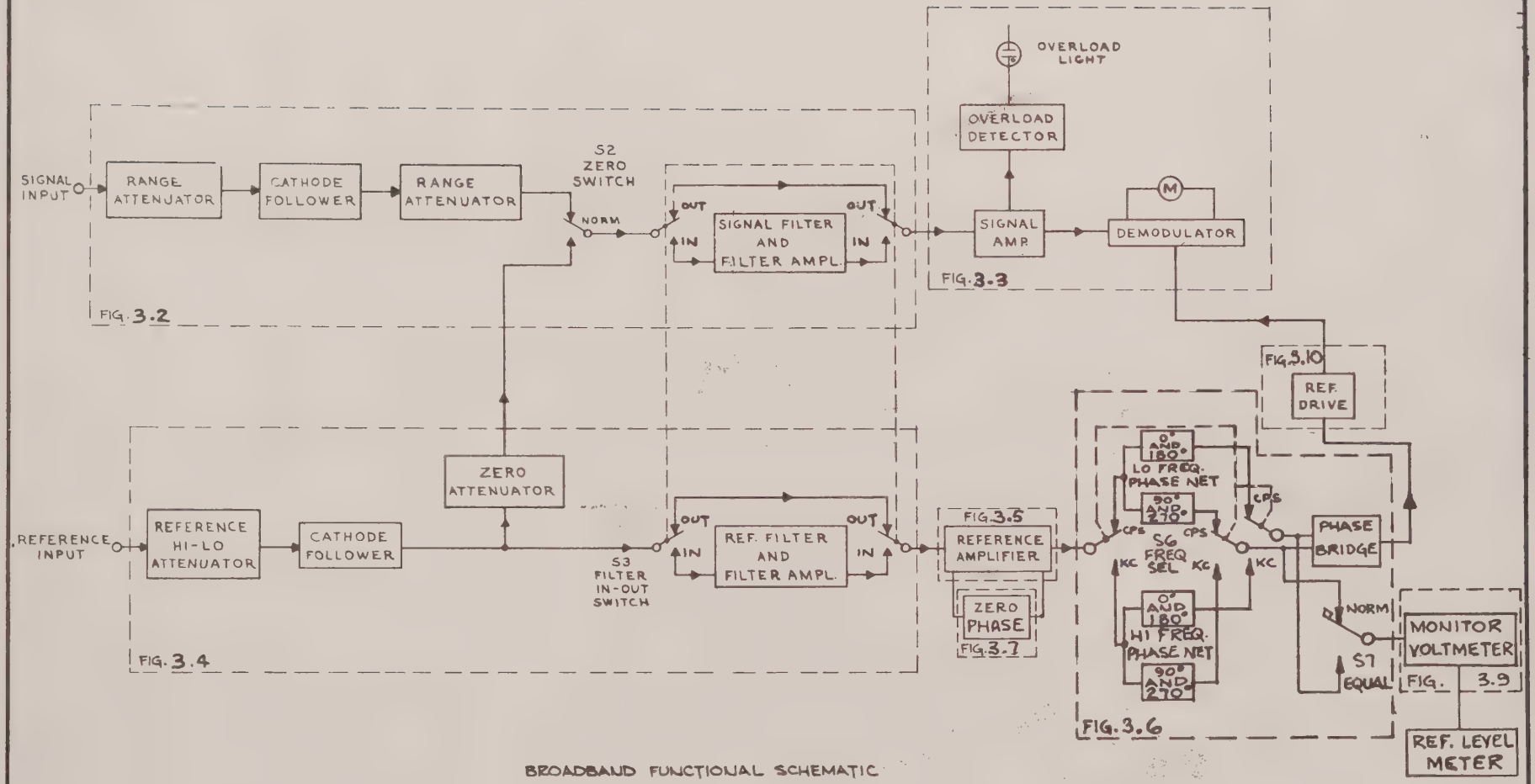
Input Attenuator and Preamplifier (Figure 3.2)

The 1,000:1 resistive divider feeds into the grid of cathode follower (V101). A six step voltage divider forms the cathode resistor for this tube. Connection for both of these attenuators is accomplished by the range switch (S1). For inputs from .001 to .3 Volts, the signal is applied directly to the grid of V101. For inputs of 1 to 300V, the signal is attenuated by 1,000:1. The six step divider switch section is arranged so that its rotor has two moving arms located 180° apart. As the range switch is rotated through its full range of rotary travel, contact is made twice with each of the six taps; once for the six low ranges, once for the six high ranges. On the six high ranges, the input signal is divided down before it is applied to the six step divider, each tap on the divider serves two ranges, giving a total of twelve ranges. Connections on both attenuators are arranged so that the output of the six step divider is maintained at approximately .001 volts which corresponds to full scale voltage for each range.

The RC networks on the six step divider serve to reduce switching transients and maintain proper ratios at all frequencies. The 1,000:1 attenuator is a broadbanded attenuator maintaining its ratio and zero phase over the entire band of frequencies.

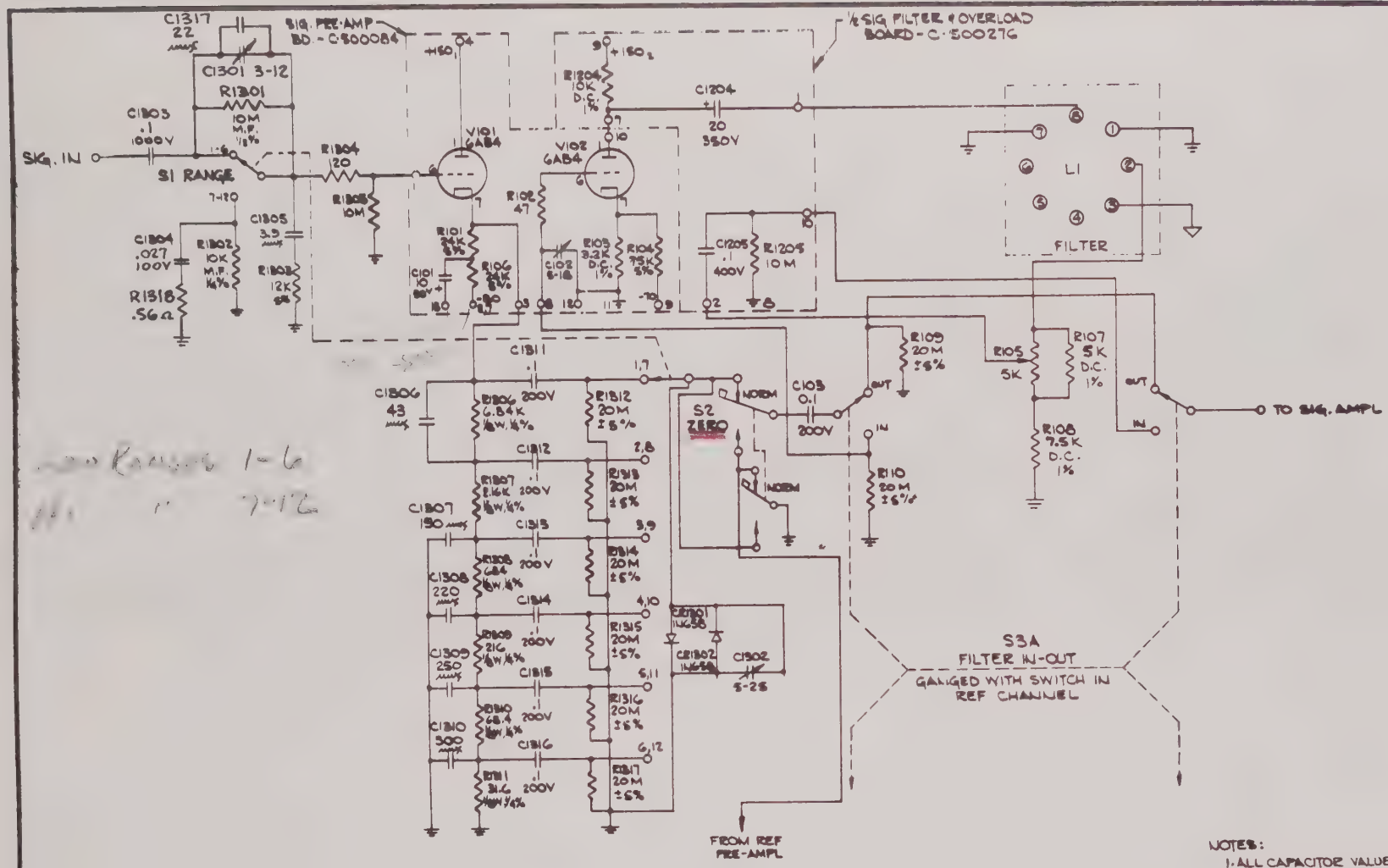
When no filters are employed, the cathode follower (V101) output is applied directly to the input of the main signal amplifier.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



BROADBAND FUNCTIONAL SCHEMATIC

FIGURE 3.1



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10%, UNLESS OTHERWISE SPECIFIED

SIG PRE-AMP

FIGURE 3.2

When filters are used, the output of the cathode follower is applied by means of the filter switch to the second 6AB4 (V102). This stage operates as a low gain amplifier to supply the proper driving impedance for the filter, and to compensate for filter insertion loss. Amplitude recalibration of the voltmeter when changing filters is accomplished by potentiometer, R105. The adjustment is located in the filter slide drawer. The proper adjustment procedure for this calibration is described under Filters.

Signal Amplifier (Figure 3.3)

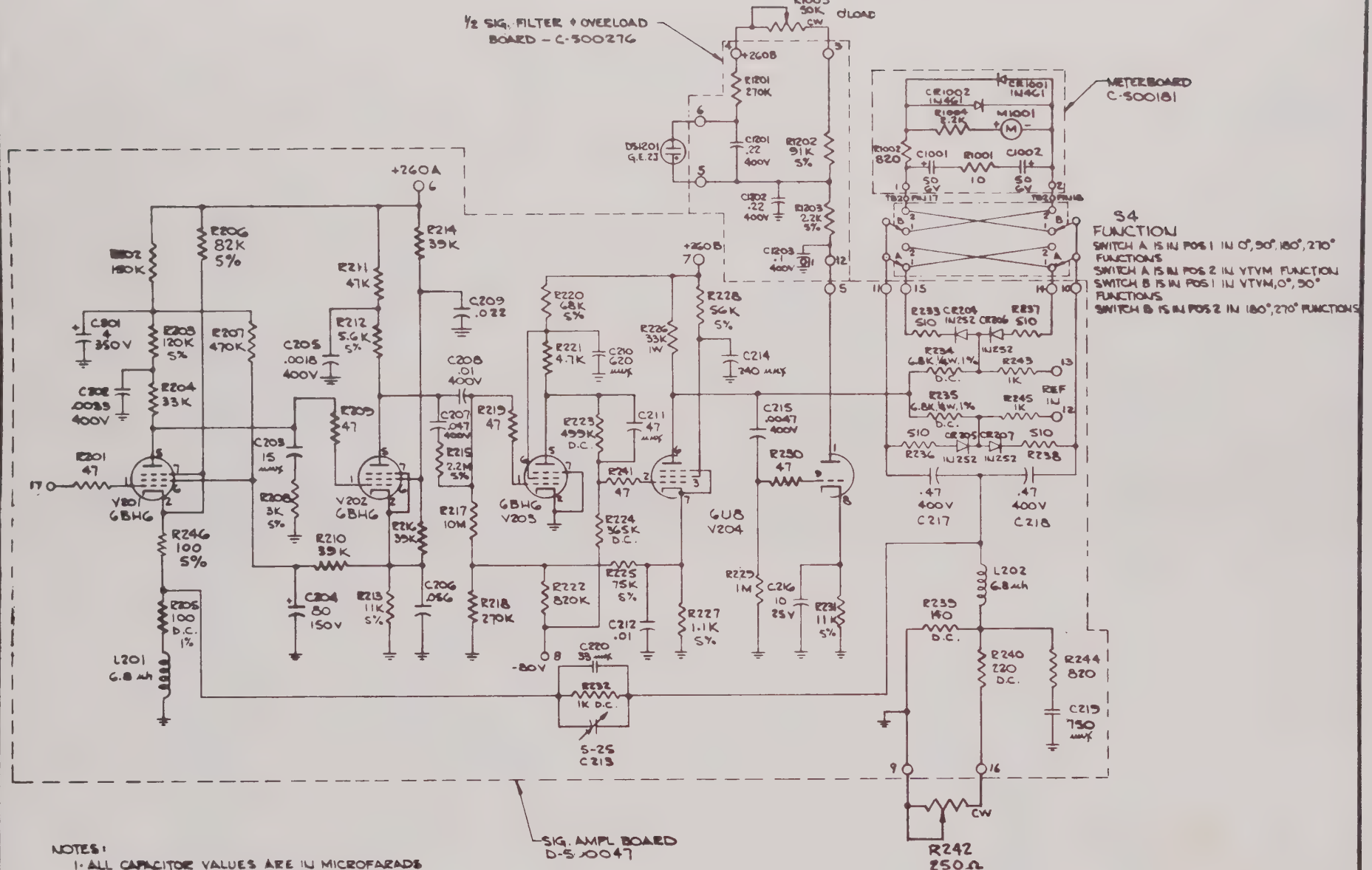
This four tube amplifier provides high gain over a wide frequency range. The output of the amplifier drives the phase sensitive detector and an indicator circuit which is biased by means of R-1202 and R-1003 in order to indicate overload conditions. A high degree of stability is obtained by the use of negative feedback. The pentode section of the dual tube (V204) drives the detector and meter circuit. The amplifier feedback is returned from the plate of this tube through the meter rectified circuit to the cathode of the first amplifier tube (V201). The overall gain of the amplifier is adjusted by means of the calibration potentiometer (R-242) located on the back panel of the voltmeter.

The second half of V204 is used to operate the overload circuit. The point at which the light illuminates is adjusted by means of potentiometer R-1003, mounted on the chassis to the rear of the Phase Pot Housing.

Reference Channel

Input Attenuator and Preamplifier (Figure 3.4)

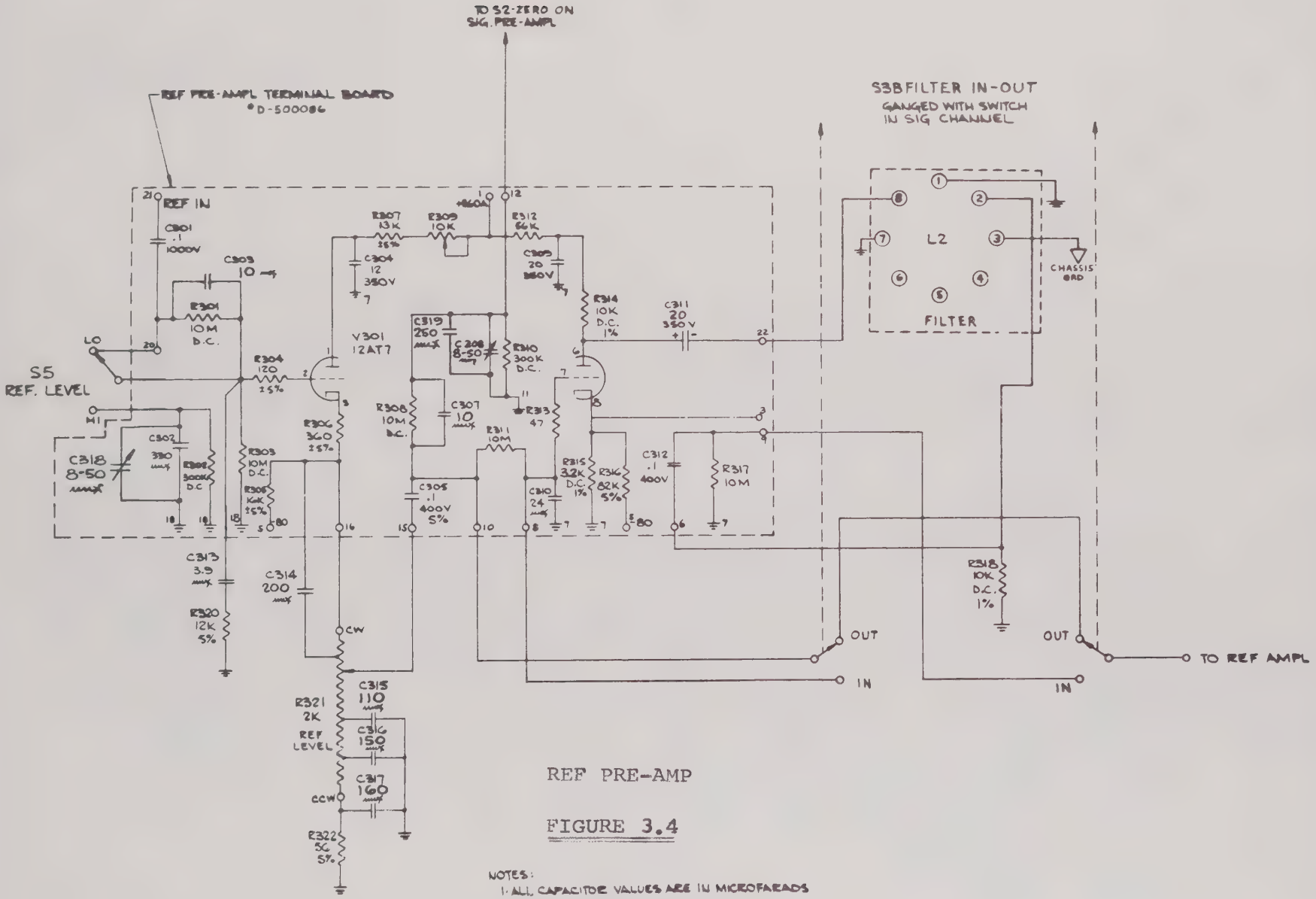
A 30:1 resistive, broadband divider feeds the grid of cathode follower (1/2 V301). A frequency compensated potentiometer forms the cathode resistor for the tube. The combination of these two attenuators allows the reference channel to be adjusted over the range of


½ SIG. FILTER & OVERLOAD BOARD – C-300276
METER BOARD C-300181
S4 FUNCTION
SWITCH A IS IN POS 1 IN 0°, 90°, 180°, 270° FUNCTIONS
SWITCH A IS IN POS 2 IN VTVM FUNCTION
SWITCH B IS IN POS 1 IN VTVM, 0°, 90° FUNCTIONS
SWITCH B IS IN POS 2 IN 180°, 270° FUNCTIONS
+260A
+260B
-80V
6BH6 V201
6BH6 V202
6BH6 V203
6U8 V204
SIG. AMPL BOARD D-5-00047
S-25 C213
R242 250Ω CAL
CW

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10% UNLESS OTHERWISE SPECIFIED

SIGNAL AMPL

FIGURE 3.3



REF PRE-AMP

FIGURE 3.4

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W ±10% UNLESS OTHERWISE SPECIFIED

.15 to 130V input.

When no filters are employed, the signal is applied directly to the grid of the first reference amplifier tube.

When a reference filter is used, the output of the cathode follower is applied by means of the filter "input" switch to the second half of V301. This stage operates as a low gain amplifier to supply the proper driving impedance for the filter and compensates for the insertion loss in the filters.

Reference Amplifier (Figure 3.5)

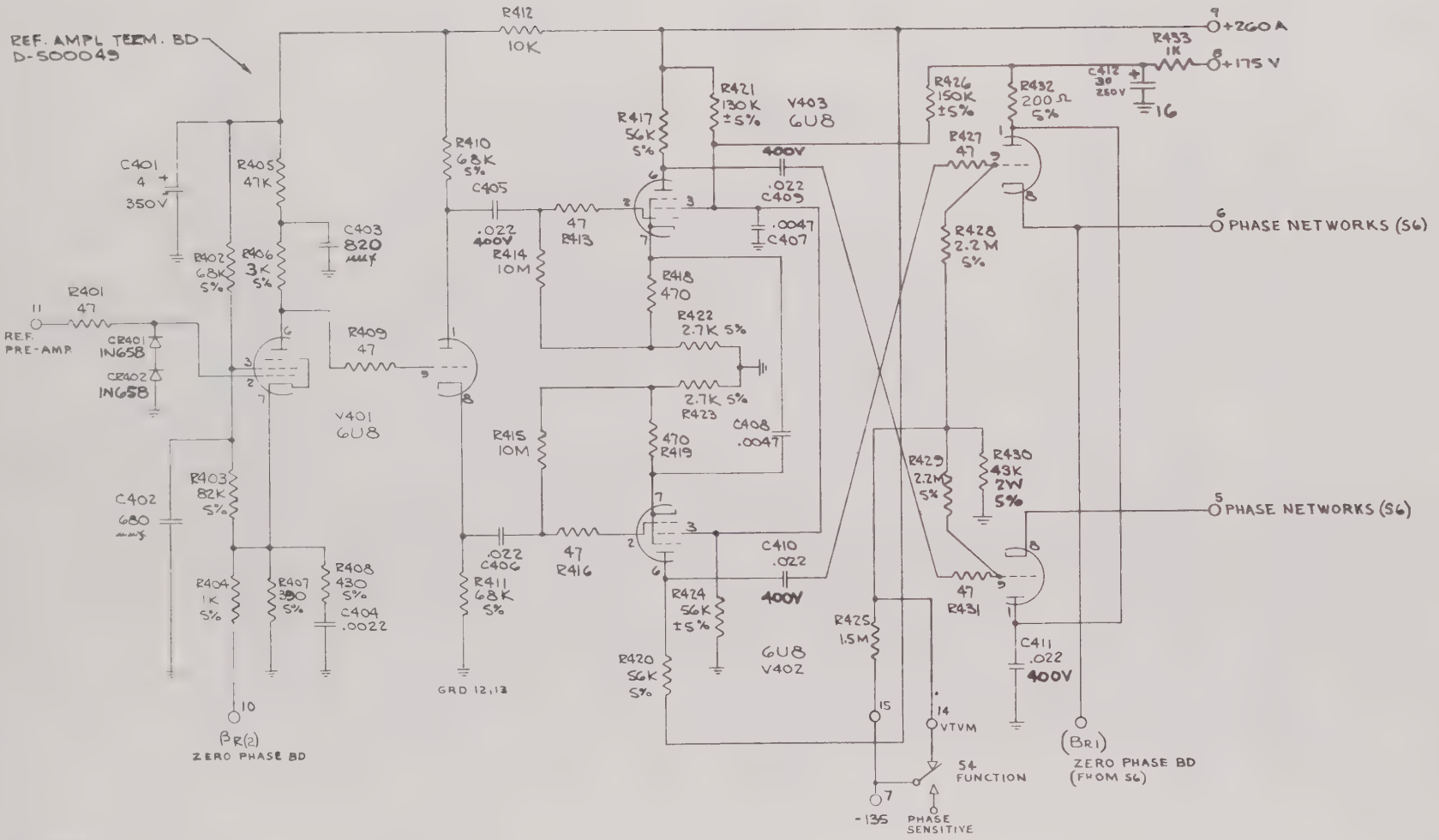
This three tube amplifier supplies the necessary gain and low impedance output required for driving the phase shifting networks. Frequency response and phase shift characteristics are carefully controlled by compensating networks in the plate and cathode circuits. Negative feedback in the cathode of the input tube is passed through networks selected by the frequency switch for proper frequency shaping. The second half of the input tube, operating as a phase shifter, feeds two cascaded, push-pull stages.

The output stage, consisting of the two triodes, operates similar to a cathode follower with transformer coupled output. In order to cover the complete frequency band, one transformer is used for the low band and a different transformer is used for the high band. The proper units is selected by the frequency switch. The feedback network of this amplifier is used to phase shift the entire reference channel when operating the "ZERO" control. Proper condensers are switched into this network as the "Frequency" Selector is rotated allowing plus and minus phase adjustments.

Phase Networks (Figure 3.6)

A unique, patented, passive phase network design is used to establish $+90^{o}$ and -90^{o} voltages. The 0^{o} and 180^{o} voltages which are derived from the center tapped secondary

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED

REFERENCE AMPLIFIER

FIGURE 3.5

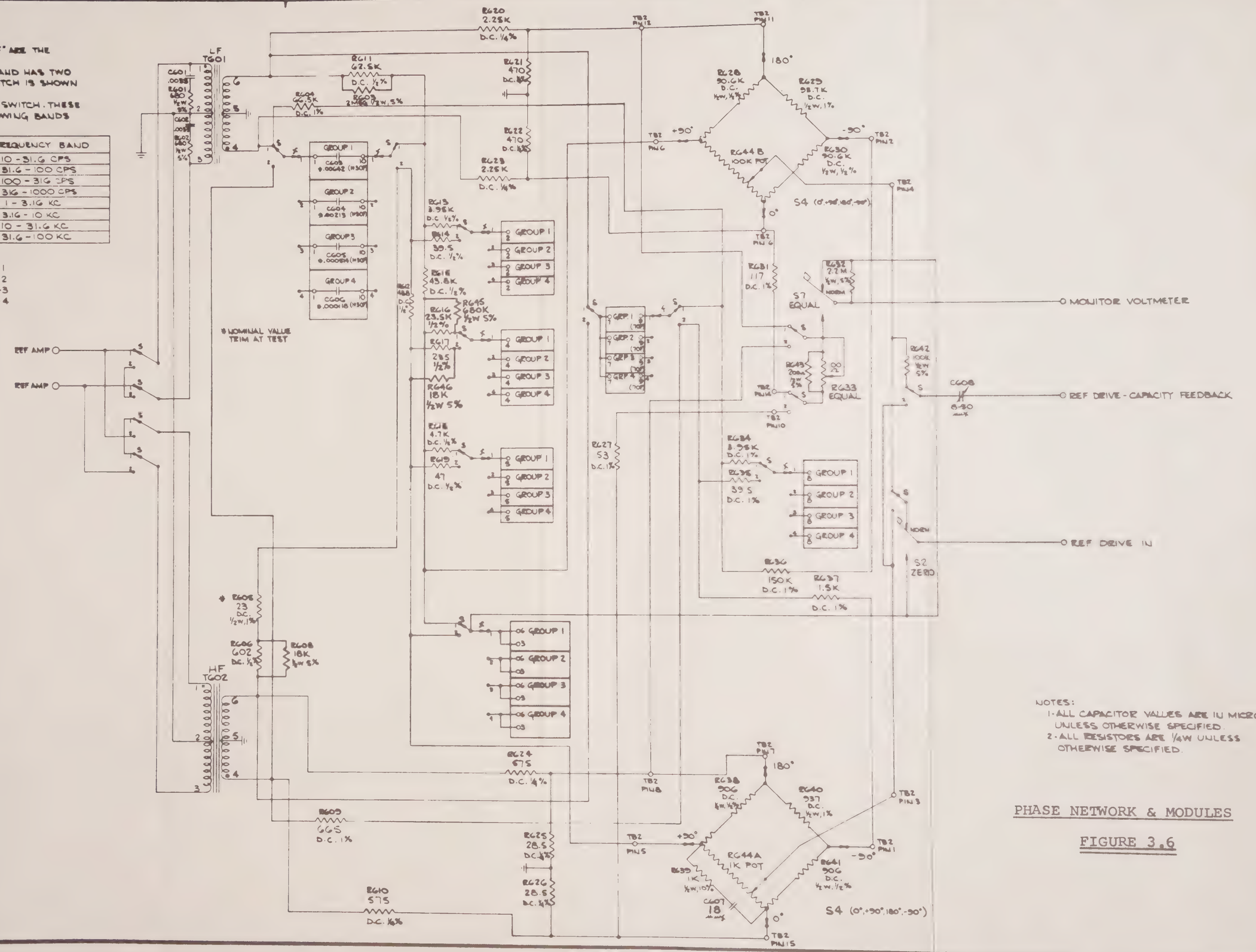
FREQUENCY SWITCH NOTES:

1. ALL SWITCHES MARKED "S" & "f" ARE THE FREQUENCY SWITCH (SG)
2. "S" IS THE SPECTRUM SWITCH AND HAS TWO POSITIONS. "CPS" & "KC". SWITCH IS SHOWN IN "CPS" POSITION.
3. "f" IS THE FREQUENCY BAND SWITCH. THESE CORRESPOND TO THE FOLLOWING BANDS OF FREQUENCY:

POSITION OF "S"	POSITION OF "f"	FREQUENCY BAND
1	1	10 - 31.6 CPS
1	2	31.6 - 100 CPS
1	3	100 - 316 CPS
1	4	316 - 1000 CPS
2	1	1 - 3.16 KC
2	2	3.16 - 10 KC
2	3	10 - 31.6 KC
2	4	31.6 - 100 KC

4. PHASE MODULES

GROUP # 1 IS NAI # D-200719-1
GROUP # 2 IS NAI # D-200719-2
GROUP # 3 IS NAI # D-200719-3
GROUP # 4 IS NAI # D-200719-4



NOTES:

1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
2. ALL RESISTORS ARE ¼W UNLESS OTHERWISE SPECIFIED.

PHASE NETWORK & MODULES

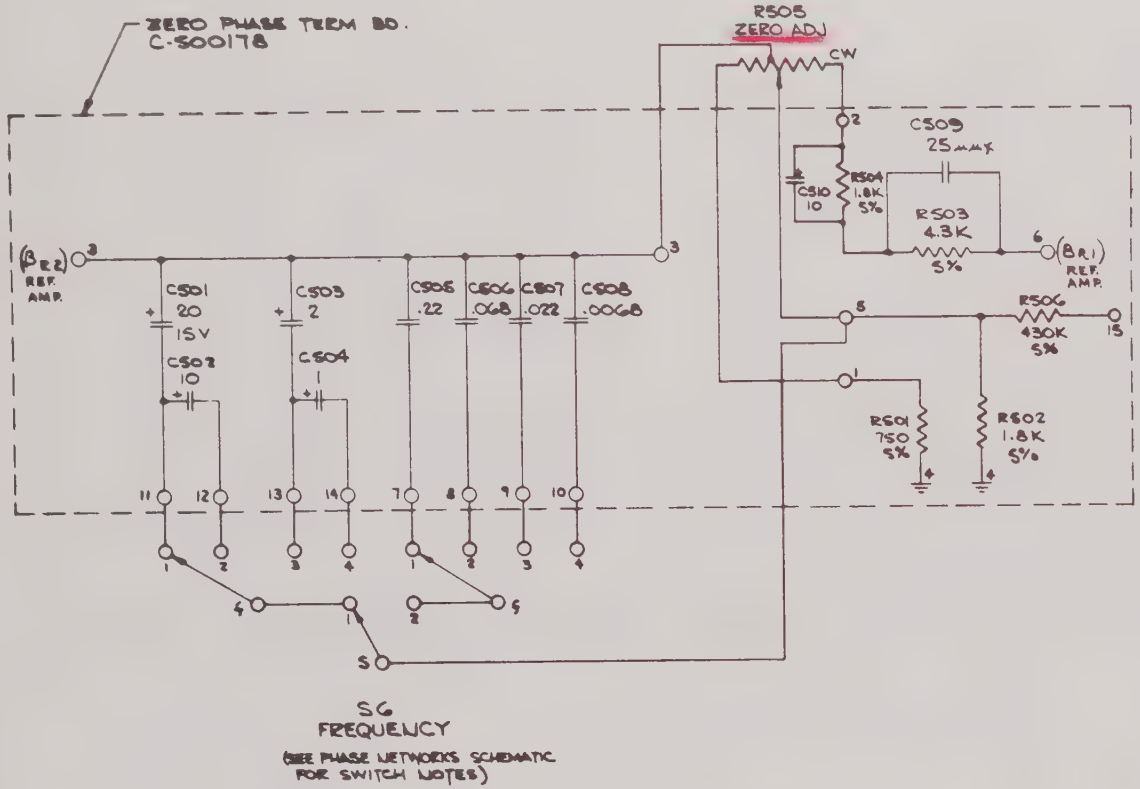
FIGURE 3.6

of the reference output transformer also represent the source for the phase networks. The four outputs resulting from this circuit configuration (0°, +90°, -90°, and 180°) are applied to a resistive bridge, one leg of which is the calibrated variable phase potentiometer. By switching the potentiometer with the Function Selector, between the 0° and 90° voltages and then between the +90° and 180° voltages, the instrument can be switched into the 0° and 90° quadrants. By repeating the above procedure and reversing the meter, the instrument is then switched into the 180° and 270° quadrants.

Zero and Equal Control (Figures 3.6 and 3.7)

These controls, which are an integral part of the phase networks, perform trimming adjustment to compensate for the frequency and amplitude characteristic of the phase network filters. Over such a large frequency range, it is inevitable that small differences in phase between the signal and reference channel occur. On conventional phase angle measuring instruments, this difference is measured by connecting the reference signal into the signal channel. If this is to be done during a measurement, then it is usually necessary to re-adjust the Range Switch, Function Selector, and Phase Dial to positions different from that used during the measurement. The "ZERO" control, on the VM-301, will automatically switch a portion of the reference through a broadband attenuator into the signal channel, at a level equivalent to a 3X overload, independent of the position of the Range Switch. This switch will also switch the instrument into the 90° position independent of the position of the "Function Selector" or the Phase Dial. Thus, one can make this adjustment in the middle of a measurement without disturbing the instrument. The "ZERO" control is a phase shifter in the reference channel, which is used to reduce the phase difference between the signal and reference channels to zero. It is noted that the input sections of both signal and reference channel contribute no phase error as a result of their careful circuit design.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED

ZERO PHASE

FIGURE 3.7

The need for the "EQUAL" control can be best illustrated by the vector diagrams shown in Figure 3.8. Figure 3.8a shows the vector voltage E that appears at the center of the phase pot when the 0° voltage is equal to the 90° voltage. It is apparent that the phase of this voltage is 45°. Figure 3.8b shows this same voltage at the center of the phase pot when the voltage is much larger than the 0° voltage. It is evident that the phase of this voltage is no longer 45°. The error that exists at 45° (point of maximum error) is 0.28°/% difference in the two magnitudes. There is no error due to this effect at 0° of 90° on the Phase Dial.

The 90° signal amplitude characteristic in each half decade of frequency follows the characteristic curve shown in Figure 3.8c for the 1KC-3.16KC band. Thus, to ensure Phase Dial accuracy at angles other than 0° and 90°, the 90° network amplitude must be adjusted so that it is equal to the in-phase amplitude. This is performed by measuring the in-phase amplitude on the monitor meter (Figure 3.9) while the EQUAL Switch is in its normal position. By depressing the EQUAL Switch, the 90° amplitude is measured through the same monitor amplifier and meter, and adjusted equal to the in-phase amplitude.

Reference Drive Amplifier (Figure 3.10)

This amplifier receives the signal from the calibrated phase potentiometer and drives the reference side of the phase sensitive detector when the Function Switch is in any of the phase sensitive positions. This amplifier is a wide band, highly stabilized, phase corrected amplifier. Its purpose is to drive the phase sensitive demodulator without using a transformer as this would severaly limit the frequency capability. The input signal is also inverted twice through V801 and V802 and fed back to the phase pot arm through C608 to unload the capacity to ground on the arm of the pot.

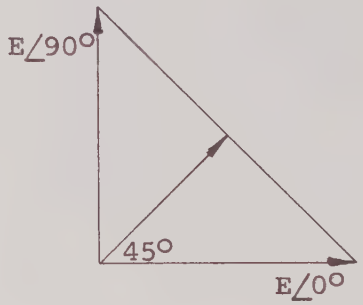


Figure 3.8a

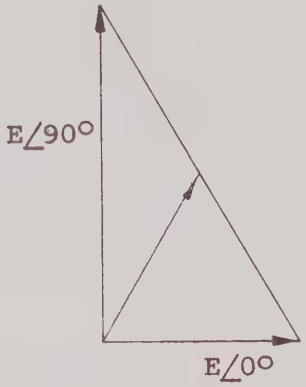


Figure 3.8b

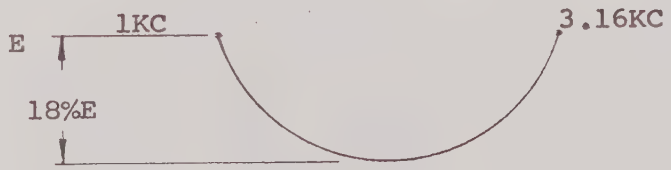
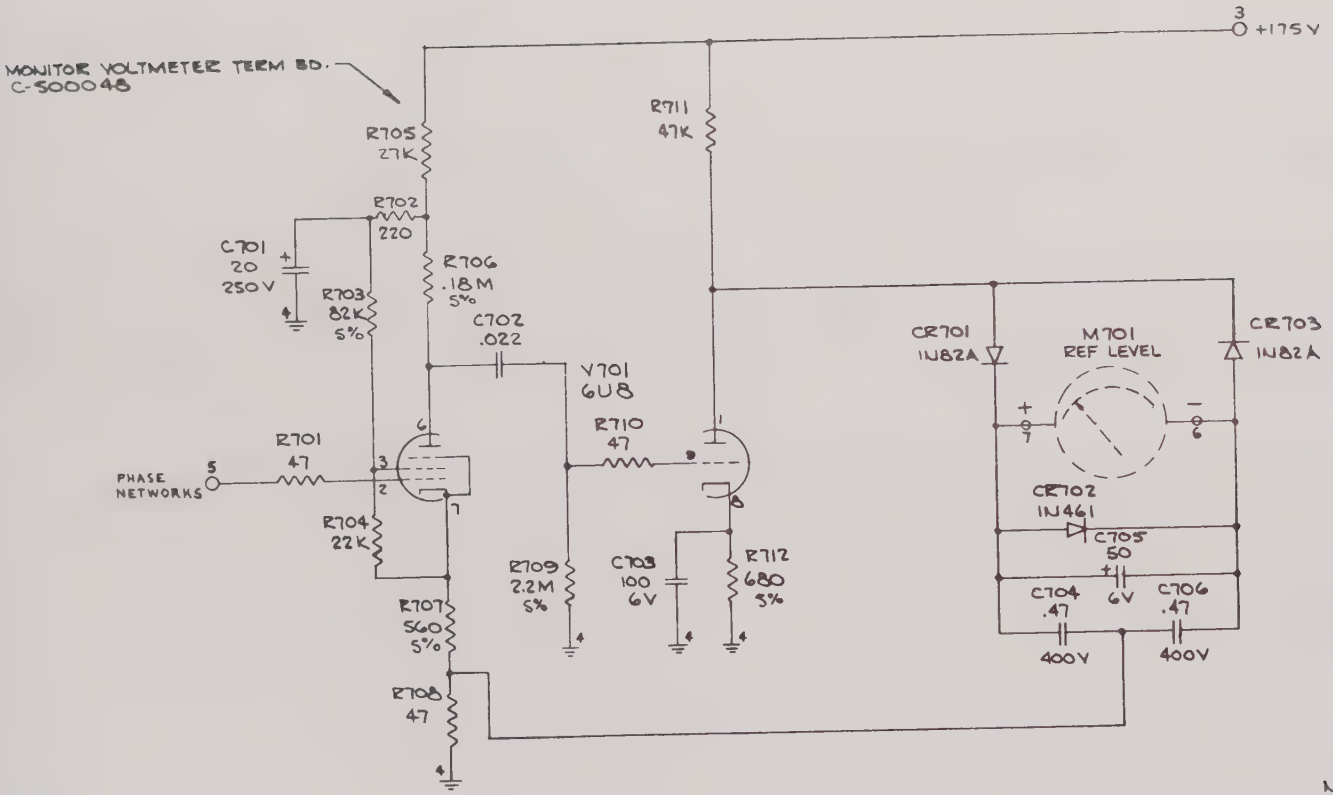


Figure 3.8c

90° Signal Amplitude Characteristics

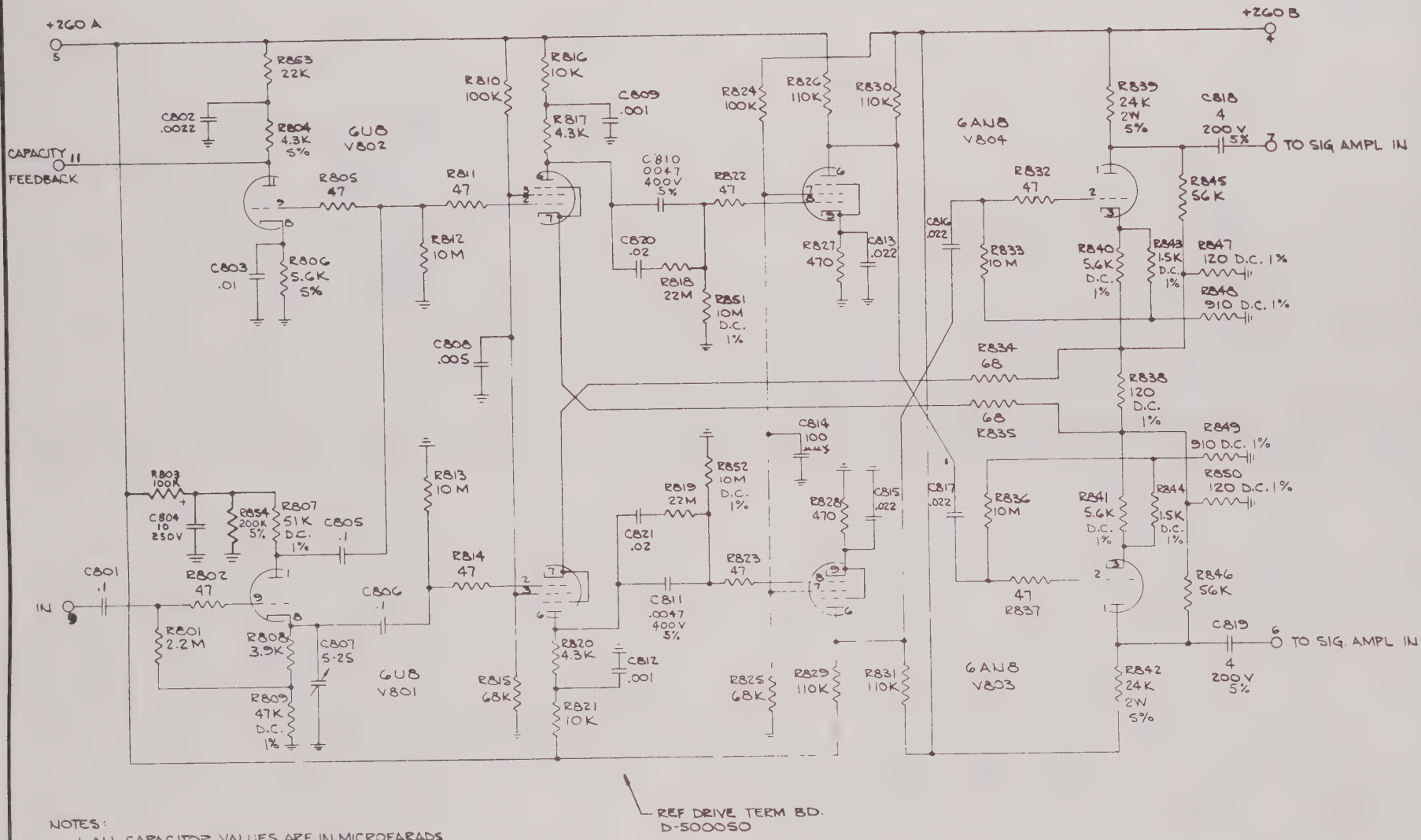
NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W, ±10% UNLESS OTHERWISE SPECIFIED

MONITOR VOLTMETER

FIGURE 3.9

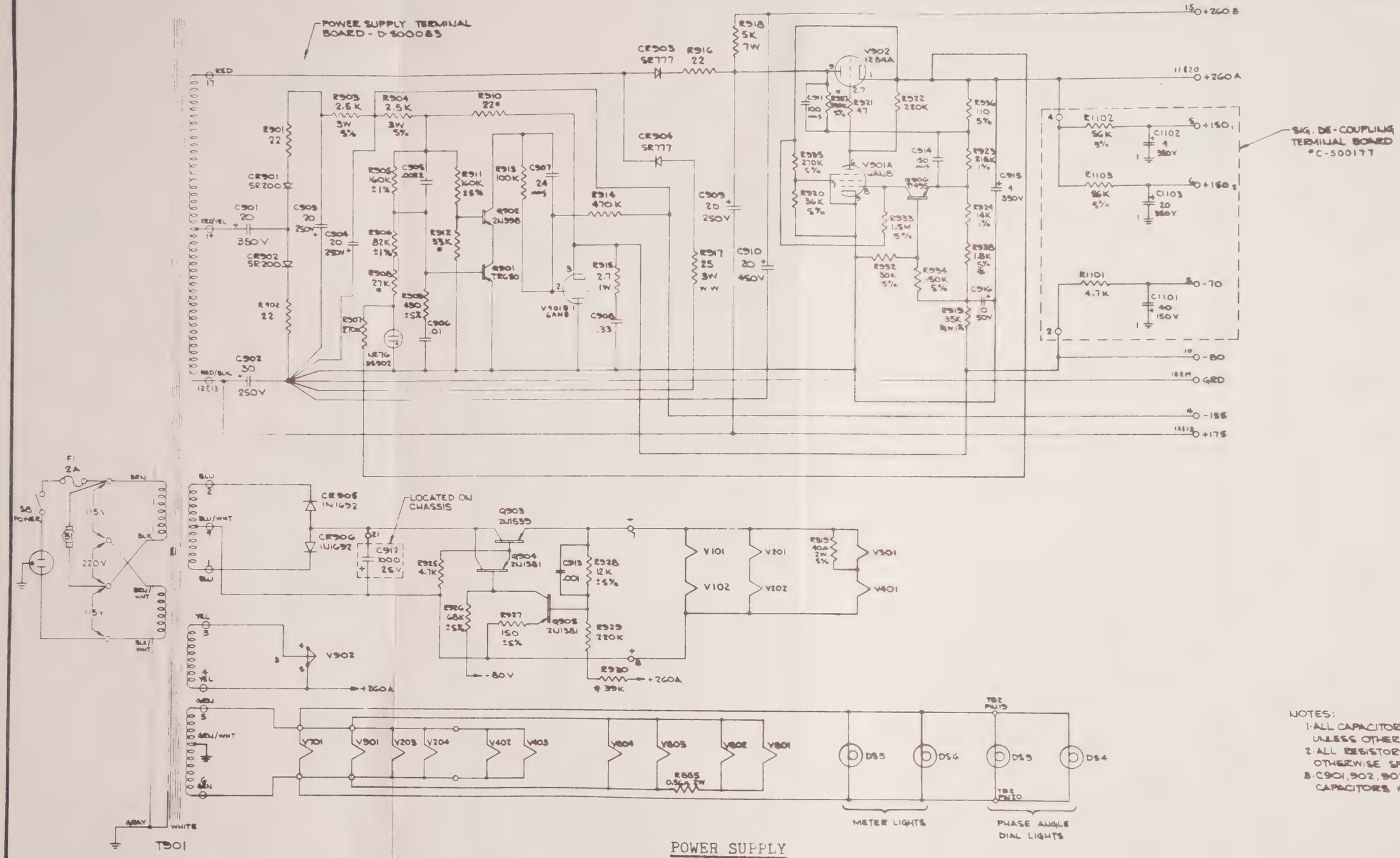


NOTES:

1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W, ±10% UNLESS OTHERWISE SPECIFIED
3 GRD PIN NO.'S 1, 8 & 10

REFERENCE DRIVE AMPLIFIER

FIGURE 3,10



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED.
3. C901, 902, 903, 909 & 912 ARE USED AS INPUT CAPACITORS WITH SILICON RECTIFIER.

POWER SUPPLY

FIGURE 3.11

Phase Sensitive Rectifier

The Phase Sensitive Rectifier circuit is a gated, bridge demodulator. Its operation can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through R242 and R220 and then the other side of the meter on the reverse cycle of the reference. The signal is, therefore, synchronously rectified through the meter movement. If the reference and signal are in phase, the average value will be a maximum and the meter will read a maximum. If the signals are 90° apart the average will be zero and no reading will result. The equation governing this is:

$$I_{Meter\ (avg)} = K\,E\cos\alpha$$

Where E = RMS of Signal

α = Angle between Signal and Reference

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. For improved accuracy under special conditions, the reference level may always be raised to maximum reading on reference level meter for high signal levels. Measurements at the quadrature null point ($\alpha = 90^{\circ}$) are unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. All other frequencies are rejected, except for signals very near the reference frequency. Here, the meter movement will oscillate between plus and minus maximums at a rate equivalent to the difference between the signal frequency and the reference frequency. Response for this type detector to odd order harmonics will never be greater than the fundamental response multiplied by a factor of 1/n where "n" is the order of the harmonic. In fact, it will usually be less and dependent upon the phase relation of the harmonic to the reference signal.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

The effect of harmonics in the reference channel are of a different nature than of the signal channel. The resultant errors are due to shifts in the point at which the diodes start to conduct. Hence, second harmonic distortion can cause errors if the zero crossover of the second harmonic is not coincident with that of the fundamental. The most significant errors due to second and even order harmonic occur when the harmonic signals are present in both channels in phase with each other, and the harmonic phase are such that they peak when the fundamental is at zero crossing. Further, this error occurs when the two channels are in fundamental quadrature with each other and may be expressed as:

$$\theta_E = 2K_S K_R \times 57.3$$

θE = angular error in degrees of phase dial.

K_S = Ratio of 2nd harmonic to Fundamental in the signal channel.

K_R = Ratio of 2nd harmonic to Fundamental in the reference channel.

For example, if 3% second harmonic distortion were present in both inputs, the error would be 0.12^o. It is noted that errors due to second harmonic in the reference channel only are small and may be generally neglected except for very large values of distortion.

Third harmonics in the reference channel only may cause an error of $K_R \times 57.3$ degrees in the relative phase of the reference if the harmonic peak when the fundamental is at zero crossing. For 3% distortion if this nature, an error of 1.7^o may result in phase dial reading.

In order to eliminate many of the above errors, when making accurate phase measurements, it is recommended that signal and reference filters be used.

Where a signal channel filter is used, there is, of course, essentially no response to harmonics in the signal channel.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

Power Supply

A special power supply is used in the VM-301, which meets the needs of the various amplifiers and circuitry throughout the unit. The particular voltages and regulation characteristics specifically designed for use in this instrument. The schematic of Figure 3.11 shows its details.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

SECTION IV

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. Detailed alignment procedures are described in Section VII. It is recommended that alignment procedures be followed only if proper test equipment and sufficiently skilled personnel are available to perform the work.

CAUTION: High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration or setting up of the instrument.

Cover Removal

A. Top and bottom covers are held in place by twelve screws each. Remove either set of twelve screws to allow removal of the corresponding top or bottom cover. (When replacing covers, be sure the open screen cover is placed on top of the voltmeter.)

B. To remove the back cover, remove the three rear screws in both the top and bottom covers, the four corner screws in the back cover, and one screw in the center of the back cover. For complete removal the fan mounting must be removed from the back panel itself.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

Tube Replacement

CAUTION: DO NO REMOVE TUBES FROM THE VOLTMETER BEFORE REMOVING POWER.

A. With the exception of Circuit V201 and V301, no circuit in the VM301 is critical to tube replacement. However, for maximum accuracy the calibrations (as described in Section VII) should be checked following tube changing.

B. When replacing V201, it will be necessary to monitor the plate voltage of V202. This is at the top of R212 (5.6K, 1/2W Resistor) located directly under the V202 tube socket on the 500047 (signal amp) component board (Figure). A V201 (6BH6) Tube should be chosen so that this voltage will be 150 ±5 volts to ground, or trim R207 for 150 ±5 volts after selecting a tube that will result in a voltage close to 150 V.

C. When replacing V301, adjust D.C. voltage on Pin 16 of 500086 (Reference Pre-Amp) to equal zero with R309.

D. Before changing the settings of any of the internal adjustments, check that the tubes are good.

Replacement of Parts

A. To remove and replace any of the tubes, it is necessary to remove the top or back covers of the instrument.

B. Most trouble-shooting can be done by removing the top, bottom, and back covers, If it is desirable to inspect the boards mounted on the inside of the rear board panel, or the terminal boards located under the power transformer, the inside rear panel may be dropped on pivots to a horizontal position. To accomplish this, remove the two screws on either side of the inside rear panel above the pivot mechanism.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

C. Although any component may easily be changed with the boards in place, should it be desirable to remove a board, remove the proper screws from the front of the board, and unsolder the wires on the terminal lugs.

D. Panel Lights in the meter box are removed from the rear of the meter by pulling the meter slide drawer forward. Panel Lights for the Phase Dial are clipmounted on the Phase Dial potentiometer housing.

E. Several resistors in the voltmeter are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used or components are moved, calibration or frequency response may be affected and re-adjustment may be required. Be careful to replace components as closely as possible in the same position the original components occupied. Pay careful attention to wiring and do not reroute or move any of the wires.

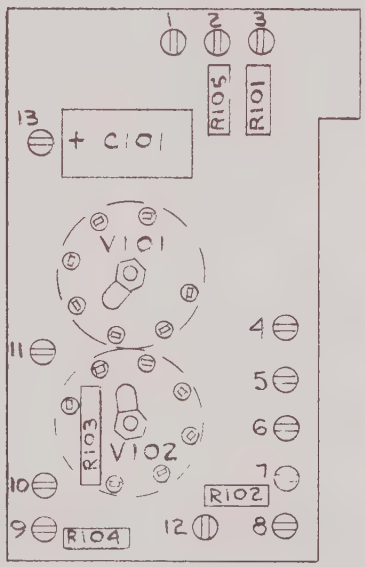
F. Transistors and semiconductor diodes are used throughout the instrument in the amplifiers, power supply, and meter circuit. If replacement is necessary, standard semiconductor practices are necessary. If any of the diodes in the meter circuits (CR 204, CR 205, CR 206, CR 207) are replaced, the voltmeter calibration, frequency, and phase calibration should be checked.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Pre-Amplifier Fig.4.1	C500084	
C101	Capacitor, Fixed, 10ufd, 50V	802209	
R101,R105	Resistor, Fixed, Comp., 24K, 1/2W, ±5%	800518	
R102	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R103	Resistor, Fixed, Dep. Carb., 3.2K, 1/2W, ±1%	802564	
R104	Resistor, Fixed, Comp., 75K, 1/2W, ±5%	800090	
V101,V102	Tube, Electron 5AB4	801070	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



SIG. PRE-AMP BOARD ASSY.
500084

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
C201	Capacitor, Fixed, 4ufd, 350V	800888	
C202	Capacitor, Fixed, .0033ufd, 400V, ±10%	802265	
C203	Capacitor, Fixed, 15uufd, 500V, ±10%	801743	
C204	Capacitor, Fixed, 80ufd, 150V	801266	
C205	Capacitor, Fixed, .0018ufd, 400V, ±10%	802236	
C206	Capacitor, Fixed, .056ufd, 200V, ±10%	802222	
C207	Capacitor, Fixed, .047ufd, 400V, ±10%	802395	
C208	Capacitor, Fixed, .01ufd, 400V, ±10%	802237	
C209	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C210	Capacitor, Fixed, 620uufd, 300V, ±10%	801746	
C211	Capacitor, Fixed, 47uufd, 500V, ±10%	801747	
C212	Capacitor, Fixed, .01ufd, 200V, ±10%	801879	
C213	Capacitor, Variable, 5025uufd	801483	
C214	Capacitor, Fixed, 240uufd, 500V, ±10%	801744	
C215	Capacitor, Fixed, .0047ufd, 400V, ±10%	802238	
C216	Capacitor, Fixed, 10ufd, 25V	801539	
C217,C218	Capacitor, Fixed, .47ufd, 400V, ±10%	800866	
C219	Capacitor, Fixed, 750uufd, 300V, ±5%	802315	
C220	Capacitor, Fixed, 33uufd, 500V, ±10%	801749	

(Continued)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
CR204,205, 206,207	Diode IN252	800840	Transitron
L201,L202	Choke 6.8uh	801742	
R201,209, 219,230, 241	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R202	Resistor, Fixed, Comp., 150K, 1/2W, ±10%	800057	
R203	Resistor, Fixed, Comp., 120K, 1/2W, ±5%	800869	
R204	Resistor, Fixed, Comp., 33K, 1/2W, ±10%	800839	
R205	Resistor, Fixed, Dep. Carb., 100Ω, 1/2W, ±1%	801592	
R206	Resistor, Fixed, Comp., 82K, 1/2W, ± 5%	801259	
R207	Resistor, Fixed, Comp., 470K, 1/2W, ±10%	800060	
R208	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R210,214, 216	Resistor, Fixed, Comp., 39K, 1/2W, ±10%	801069	
R211	Resistor, Fixed, Comp., 47K, 1/2W, ±10%	800087	

(Continued)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
R212	Resistor, Fixed, Comp., 5.6K, 1/2W, ±5%	800641	
R213,231	Resistor, Fixed, Comp., 11K, 1/2W, ±5%	800620	
R215	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R217	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R218	Resistor, Fixed, Comp., 270K, 1/2W, ±10%	800059	
R220	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R221	Resistor, Fixed, Comp., 4.7K, 1/2W, ±10%	800078	
R222	Resistor, Fixed, Comp., 820K, 1/2W, ±10%	801598	
R223	Resistor, Fixed, Dep. Carb., 499K, 1/2W, ±1%	801597	
R224	Resistor, Fixed, Dep. Carb., 365K, 1/2W, ±1%	801596	
R225	Resistor, Fixed, Comp., 75K, 1/2W, ±5%	800090	
R227	Resistor, Fixed, Comp., 1.1K, 1/2W, ±5%	801595	
R228	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	

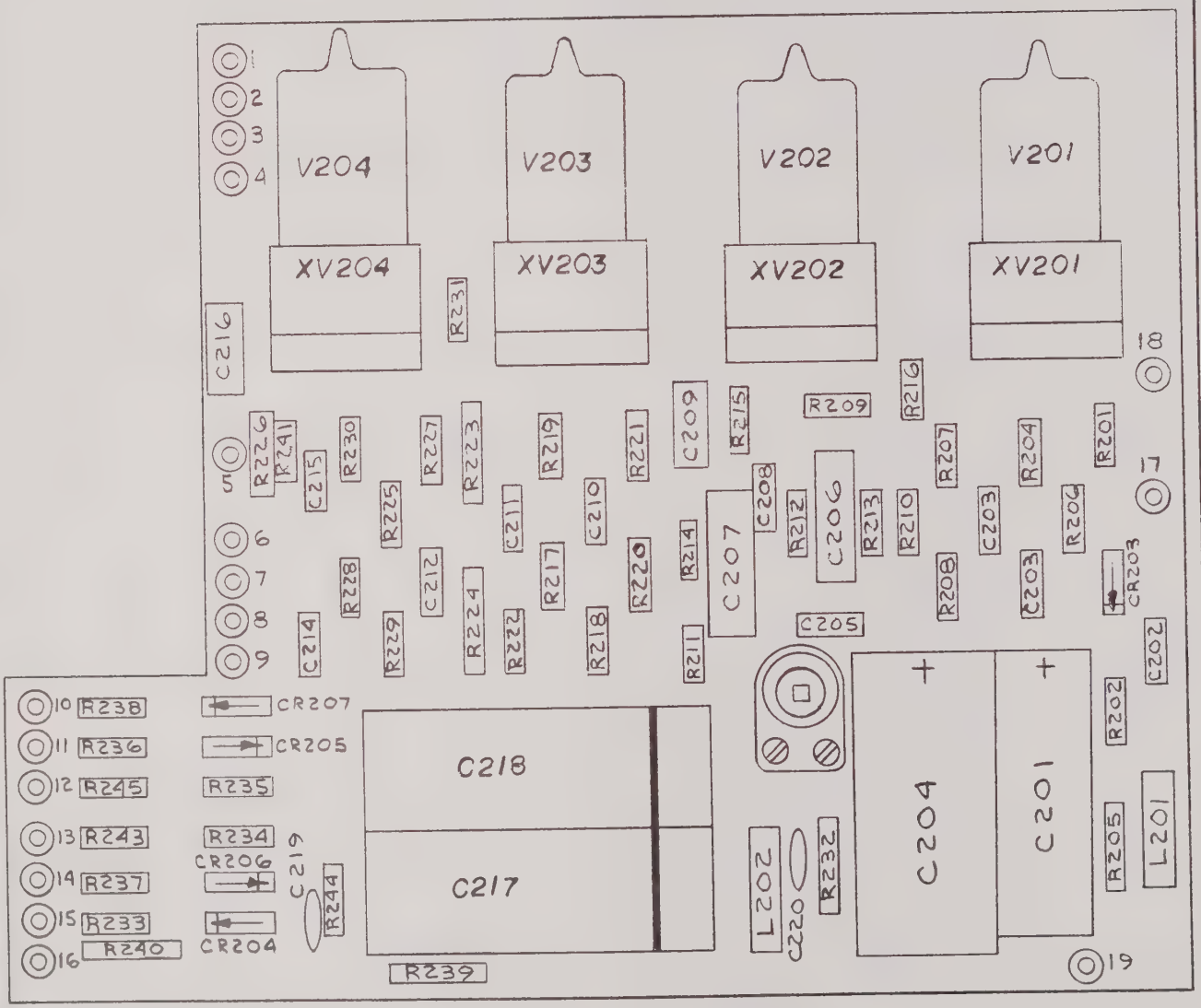
(Continued) 4.8

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
R229	Resistor, Fixed, Comp., 1 M, 1/2W, ±10%	800063	
R232	Resistor, Fixed, Dep. Carb., 1K, 1/2W, ±1%	801136	
R233,236, 237,238	Resistor, Fixed, Comp., 510Ω, 1/2W, ±5%	800525	
R234,235	Resistor, Fixed, Dep. Carb., 6.8K, 1/4W, ±1%	802464	
R239	Resistor, Fixed, Dep. Carb., 140Ω, 1/2W, ±1%	802376	
R240	Resistor, Fixed, Dep. Carb., 220Ω, 1/2W, ±1%	801591	
R243,245	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	
R244	Resistor, Fixed, Comp., 820Ω, 1/2W, ±10%	800082	
R246	Resistor, Fixed, Comp., 100Ω, 1/2W, ±5%	800631	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



SIG. AMPL. BOARD ASSY.
500047

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Pre-Amplifier (Figure 4.3)	D500086	
C301	Capacitor, Fixed, .1ufd, 1000V, ±10%	801068	
C302	Capacitor, Fixed, 330uufd, 200V, ±10%	802242	Special
C303,307	Capacitor, Fixed, 10uufd, 500V, ±5%	802561	Special
C304	Capacitor, Fixed, 12ufd, 350V,	801023	
C305	Capacitor, Fixed, .1ufd, 400V, ±5%	802262	
C308,318	Capacitor, Variable, 8-50uufd	800854	Special
C309,311	Capacitor, Fixed, 20ufd, 350V	800847	
C310	Capacitor, Fixed, 24uufd, 500V, ±5%	802170	
C312	Capacitor, Fixed, .1ufd, 400V, ±20%	800020	
C319	Capacitor, Fixed, 250uufd, 500V, ±5%	802310	Special
R301	Resistor, Fixed, Dep. Carb., 10M, 1W, ±1%	801507	
R303,308	Resistor, Fixed, Dep. Carb., 10M, 1W, ±1%	802253	
R302	Resistor, Fixed, Dep. Carb., 300K 1W, ±1%	801165	
R304	Resistor, Fixed, Comp., 120Ω, 1/2W, ±5%	800407	
R305	Resistor, Fixed, Comp., 16K, 1/2W, ±5%	800619	

(Continued)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Pre-Amplifier (Figure 4.3)	D500086	
R306	Resistor, Fixed, Comp, 360Ω, 1/2W, ±5%	801654	
R307	Resistor, Fixed, Comp., 13K, 1/2W, ±5%	800637	
R309	Resistor, Variable, 10K, 2W, ±10%	801750	
R310	Resistor, Fixed, Dep. Carb., 300K, 1/2W, ±1%	801165	
R311,317	Resistor, Fixed, Comp., 10 MΩ, 1/2W, ±10%	801025	
R312	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800498	
R313	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R314	Resistor, Fixed, Dep. Carb., 10K, 1/2W, ±1%	801481	
R315	Resistor, Fixed, Dep. Carb., 3.2K, 1/2W, ±1%	802564	
R316	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R319	Resistor, Fixed, W.W., 40Ω, 2W, ±5%	802328	
V301	Tube, Electron, 12AT7	801019	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Pre-Amplifier (Figure 4.3)	D500086	
C301	Capacitor, Fixed, .1ufd, 1000V, ±10%	801068	
C302	Capacitor, Fixed, 330uufd, 200V, ±10%	802242	Special
C303,307	Capacitor, Fixed, 10uufd, 500V, ±5%	802561	Special
C304	Capacitor, Fixed, 12ufd, 350V,	801023	
C305	Capacitor, Fixed, .1ufd, 400V, ±5%	802262	
C308,318	Capacitor, Variable, 8-50uufd	800854	Special
C309,311	Capacitor, Fixed, 20ufd, 350V	800847	
C310	Capacitor, Fixed, 24uufd, 500V, ±5%	802170	
C312	Capacitor, Fixed, .1ufd, 400V, ±20%	800020	
C319	Capacitor, Fixed, 250uufd, 500V, ±5%	802310	Special
R301	Resistor, Fixed, Dep. Carb., 10M, 1W, ±1%	801507	
R303,308	Resistor, Fixed, Dep. Carb., 10M, 1W, ±1%	802253	
R302	Resistor, Fixed, Dep. Carb., 300K 1W, ±1%	801165	
R304	Resistor, Fixed, Comp., 120Ω, 1/2W, ±5%	800407	
R305	Resistor, Fixed, Comp., 16K, 1/2W, ±5%	800619	

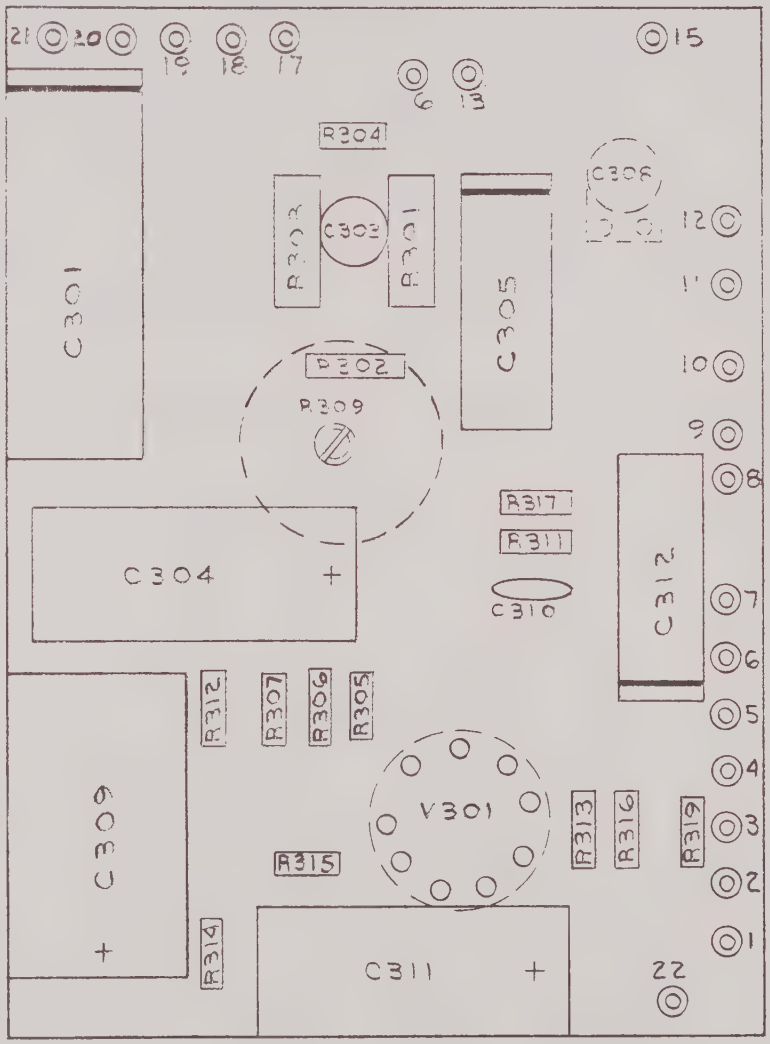
(Continued) 4.11

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Pre-Amplifier (Figure 4.3)	D500086	
R306	Resistor, Fixed, Comp, 360Ω, 1/2W, ±5%	801654	
R307	Resistor, Fixed, Comp., 13K, 1/2W, ±5%	800637	
R309	Resistor, Variable, 10K, 2W, ±10%	801750	
R310	Resistor, Fixed, Dep. Carb., 300K, 1/2W, ±1%	801165	
R311,317	Resistor, Fixed, Comp., 10 MΩ, 1/2W, ±10%	801025	
R312	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800498	
R313	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R314	Resistor, Fixed, Dep. Carb., 10K, 1/2W, ±1%	801481	
R315	Resistor, Fixed, Dep. Carb., 3.2K, 1/2W, ±1%	802564	
R316	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R319	Resistor, Fixed, W.W., 40Ω, 2W, ±5%	802328	
V301	Tube, Electron, 12AT7	801019	

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*



REF. PRE-AMPL. ASSY.
500086

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Amplifier (Fig.4.4)	D500049	
C401	Capacitor, Fixed, 4ufd, 350V	800888	
C402	Capacitor, Fixed, 680uufd, 300V, ±5%	801787	
C403	Capacitor, Fixed, 820uufd, 500V, ±10%	802344	
C404	Capacitor, Fixed, .0022ufd, 200V, ±10%	802217	
C405,509 410,411	Capacitor, Fixed, .022ufd, 400V, ±10%	802235	
C406	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C407,408	Capacitor, Fixed, .0047ufd, 200V, ±10%	802239	
C412	Capacitor, Fixed, 30ufd, 250V	801528	
CR401,402	Diode, Silicon, IN658	801661	
R401,409, 413,416, 427,431	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R402,410 411	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R403	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R404	Resistor, Fixed, Comp., 1K, 1/2W, ±5%	800414	
R405	Resistor, Fixed, Comp., 47K, 1/2W, ±10%	800087	
R406	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	

(Continued)

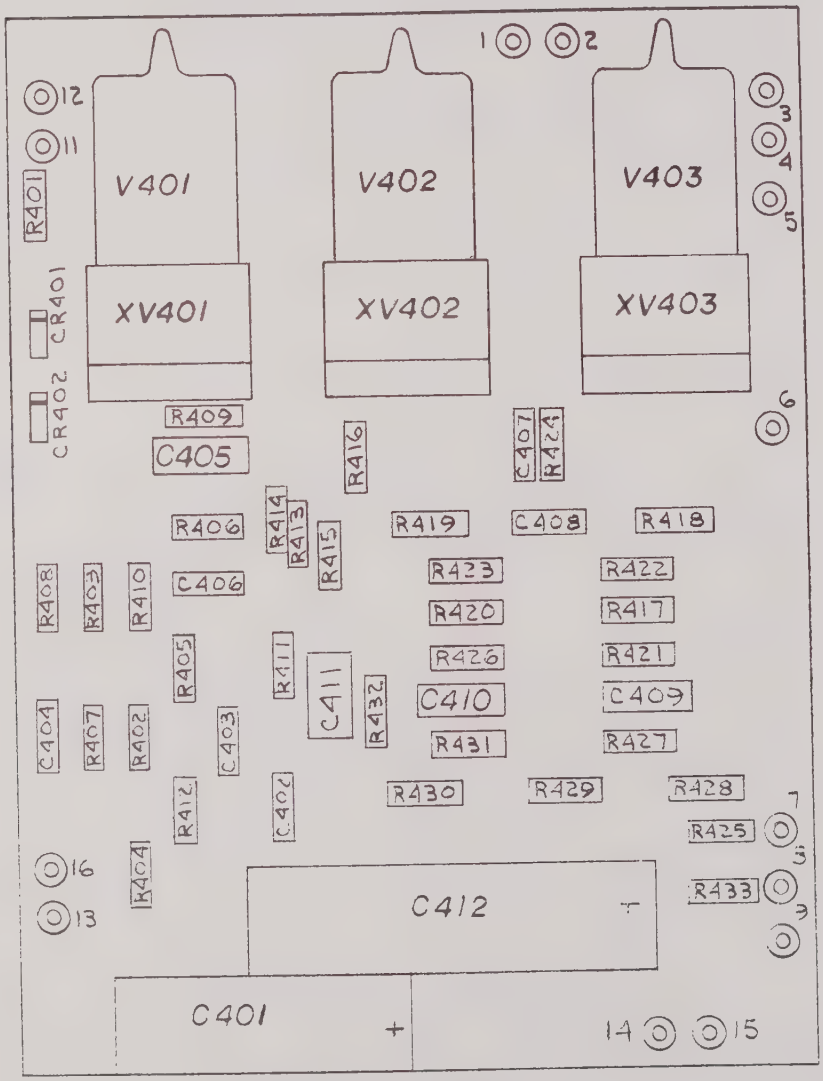
NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Amplifier, (Fig.4.4)	D500049	
R407	Resistor, Fixed, Comp., 390Ω, 1/2W, ±5%	800629	
R408	Resistor, Fixed, Comp., 430Ω, 1/2W, ±5%	800640	
R412	Resistor, Fixed, Comp., 10K, 1/2W, ±10%	800089	
R414,415	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R417,420, 424	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R418,419,	Resistor, Fixed, Comp., 470Ω, 1/2W, ±10%	800084	
R421	Resistor, Fixed, Comp., 130K, 1/2W, ±5%	800806	
R422,423	Resistor, Fixed, Comp., 2.7K, 1/2W, ±5%	800643	
R425	Resistor, Fixed, Comp., 1.5M, 1/2W, ±10%	800378	
R426	Resistor, Fixed, Comp., 150K, 1/2W, ±10%	800057	
R428,429	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R430	Resistor, Fixed, Comp., 43K, 1/2W, ±5%	801024	
R432	Resistor, Fixed, Comp., 200Ω, 1/2W, ±5%	801672	
R433	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	
V401,402, 403	Tube, Electron, 6U8	800028	

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600



REF. AMPL. ASSY.
500049

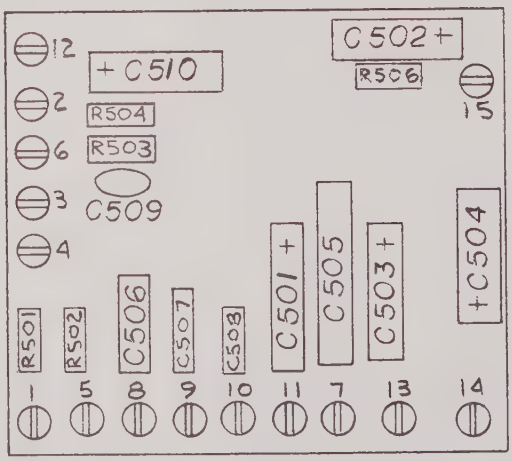
NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Zero Phase (Fig.4.5)	C500178	
C501	Capacitor, Fixed, 20ufd, 15V	801551	
C502,510	Capacitor, Fixed, 10ufd, 15V	801550	
C503	Capacitor, Fixed, 2 ufd, 15V	801549	
C504	Capacitor, Fixed, 1ufd, 15V	801548	
C505	Capacitor, Fixed, .22ufd, 200V, ±10%	802233	
C506	Capacitor, Fixed, .068ufd, 200V, ±10%	802225	
C507	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C508	Capacitor, Fixed, .0068ufd, 200V, ±10%	802224	
C509	Capacitor, Fixed, 25uufd, 600V, ±5%	801543	
R501	Resistor, Fixed, Comp., 750Ω, 1/2W, ±5%	800911	
R502,504	Resistor, Fixed, Comp., 1.8K, 1/2W, ±5%	800858	
R503	Resistor, Fixed, Comp., 4.3K, 1/2W, ±5%	800621	
R506	Resistor, Fixed, Comp., 430K, 1/2W, ±5%	802470	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



ZERO PHASE BOARD ASSY.
500178

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
S4	Assembly, Function Switch	500230	
R629	Resistor, Fixed, Dep. Carb., 93.7K, 1/2W, ±1%	801622	
R640	Resistor, Fixed, Dep. Carb., 937Ω, 1/4W, ±1%	801621	
S6	Assembly, Frequency Switch	500231	
C608	Capacitor, Variable, 8050uufd	800854	
R603	Resistor, Fixed, Comp., 2M, 1/2W, ±5%	802173	
R604	Resistor, Fixed. Dep. Carb., 66.5K, 1/4W, ±1%	801710	
R606	Resistor, Fixed, Dep. Carb., 602Ω, 1/4W, ±1/2%	801701	
R609	Resistor, Fixed, Dep. Carb., 665Ω, 1/4W, ±1%	801702	
R611	Resistor, Fixed, Dep. Carb., 62.5K, 1/4W, ±1/2%	801709	
R612	Resistor, Fixed, Dep. Carb., 438Ω, 1/4W,±1/2%	801698	
R613	Resistor, Fixed, Dep. Carb., 3.95K, 1/4W, ±1/2%	801705	
R614	Resistor, Fixed, Dep. Carb., 39.5Ω, 1/4W, ±1/2%	801692	
R615	Resistor, Fixed, Dep. Carb., 43.8K, 1/4W, ±1/2%	801708	
R616	Resistor, Fixed, Dep. Carb., 23.5K, 1/4W, ±1/2%	801707	

(Continued) 4.19

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
S6	Assembly, Frequency Switch	500231	
R617	Resistor, Fixed, Dep. Carb., 235Ω, 1/4W, ±1/2%	801697	
R618	Resistor, Fixed, Dep. Carb., 4.7K, 1/4W, ±1/2%	801706	
R619	Resistor, Fixed, Dep. Carb., 47Ω, 1/4W, ±1/2%	801694	
R634	Resistor, Fixed, Dep. Carb., 3.95K, 1/4W, ±1%	800820	
R635	Resistor, Fixed, Dep. Carb., 39.5Ω, 1/4W, ±1%	801693	
R636	Resistor, Fixed, Dep. Carb., 150K, 1/4W, ±1%	802451	
R637	Resistor, Fixed, Dep. Carb., 1.5K, 1/4W, ±1%	802248	
R642	Resistor, Fixed, Comp., 100K, 1/2W, ±5%	800520	
R646	Resistor, Fixed, Comp., 18K, 1/2W, ±5%	800611	
TB6	Assembly, Terminal Board	500292	
C601,602	Capacitor, Fixed, .0033ufd, 200V, ±10%	802221	
R601, 602	Resistor, Fixed, Comp., 680Ω, 1/2W, ±5%	800638	
R610,624	Resistor, Fixed, Dep. Carb., 575Ω, 1/4W, ±1/4%	801700	
R620,623	Resistor, Fixed, Dep. Carb., 2.25K, 1/4W, ±1/4%	801704	
R621,622	Resistor, Fixed, Dep. Carb., 470Ω, 1/4W, ±1/4%	801699	
R645	Resistor, Fixed, Comp., 680K, 1/2W, ±5%	801875	

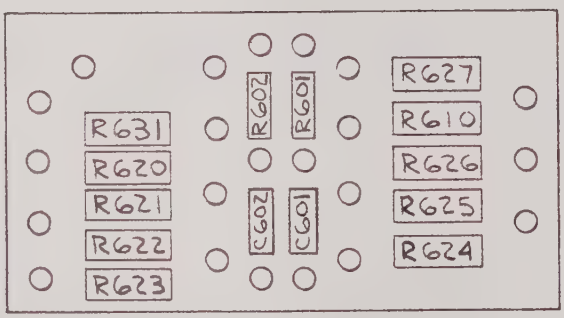
NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
TB6	Assembly, Terminal Board	500292	
R625,626	Resistor, Fixed, Dep. Carb., 28.5Ω, 1/4W, ±1.4%	801691	
R627	Resistor, Fixed, Dep. Carb., 53Ω, 1/4W, ±1%	801695	
R631	Resistor, Fixed, Dep. Carb., 117Ω, 1/4W, ±1%	801696	
R644	Assembly, Phase Potentiometer (Dual) R644A = 1K, R644B = 100K	801363	
TB3	Terminal Board	500298	
C607	Capacitor, Fixed, 18uufd, 500V, ±5%	802423	
R628,630	Resistor, Fixed, Dep. Carb., 90.6K, 1/2W, ±1%	801514	
R638,641	Resistor, Fixed, Dep. Carb., 906Ω, 1/2W, ±1%	801513	
R639	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	
TB1	Assembly, Terminal Board (Phase Network Module Trim)	201433	
C603,604, 605,606	Selected at test		
R605	Selected at test.		

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



TERM. BOARD ASSY. (TB6)
500292

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Monitor Voltmeter Terminal Board, Figure 4.6	500048	
C701	Capacitor, Fixed, 20ufd, 250V	801221	
C702	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C703	Capacitor, Fixed, 100ufd, 6V,	800600	
C704,706	Capacitor, Fixed, .47ufd, 400V, ±10%	800866	
C705	Capacitor, Fixed, 50ufd, 6V	800163	
CR701,703	Diode, IN82A	800867	
CR702	Diode, IN461	800942	
R701,708 710	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R702	Resistor, Fixed, Comp., 220Ω, 1/2W, ±10%	802301	
R703	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R704	Resistor, Fixed, Comp., 22K, 1/2W, ±10%	800155	
R705	Resistor, Fixed, Comp., 27K, 1/2W, ±10%	800088	
R706	Resistor, Fixed, Comp., 180K, 1/2W, ±5%	801260	
R707	Resistor, Fixed, Comp., 560Ω, 1/2W, ±5%	801258	
R709	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R711	Resistor, Fixed, Comp., 47K, 1/2W, ±10%	800087	
R712	Resistor, Fixed, Comp., 680Ω, 1/2W, ±5%	800638	

(Continued)

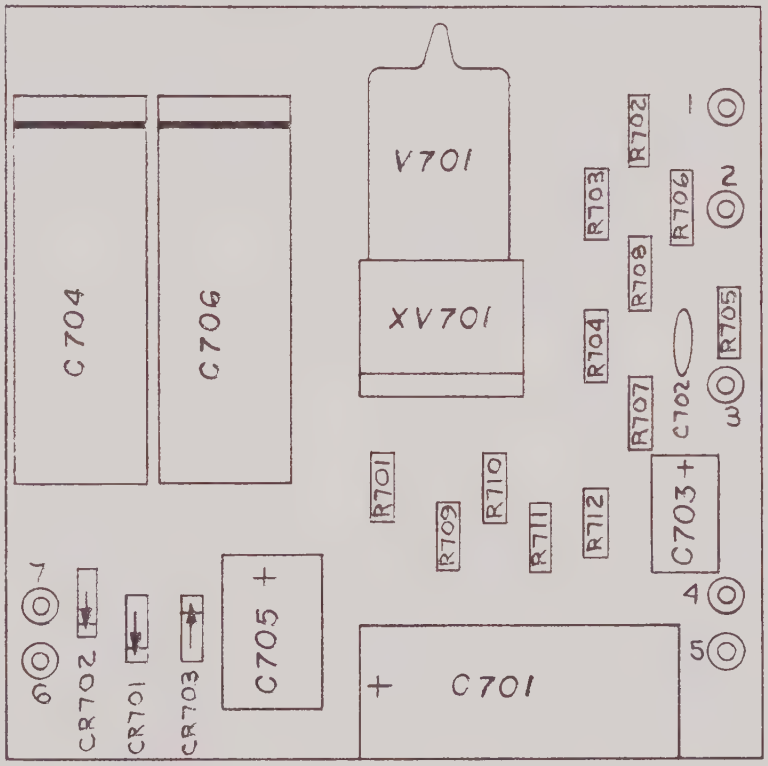
NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Monitor Voltmeter Terminal Board, Figure 4.6	500048	
V701	Tube, Electron 6U8	800028	
M701	Meter, Ref. Level	800565	

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*



MONITOR VOLTMETER TERMINAL BOARD ASSY.
500048

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.7	500050	
C801,805 806,	Capacitor, Fixed, .1ufd, 200V, ±10%	802220	
C802	Capacitor, Fixed, .0022ufd, 400V, ±10%	802240	
C803	Capacitor, Fixed, .01ufd, 200V, ±10%	801789	
C804	Capacitor, Fixed, 10ufd, 250V,	801227	
C807	Capacitor, Variable, 5-25uuf	801483	
C808	Capacitor, Fixed, .0047ufd, 200V,±10%	802239	
C809,812	Capacitor, Fixed, .001ufd, 400V, ±10%	802241	
C810,811	Capacitor, Fixed, .0047ufd, 400V, ±5%	802281	
C813,815	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C814	Capacitor, Fixed, 100uufd, 500V, ±5%	801264	
C816,817 920,821	Capacitor, Fixed, .022uufd, 400V,±10%	802235	
C818,819	Capacitor, Fixed, 4ufd, 200V, ±5%	802245	
R801	Resistor, Fixed, Comp., 2.2M,1/2W,±5%	800064	
R802,805, 811,814, 822,823, 832,837	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R803,810 824	Resistor, Fixed, Comp., 100K, 1/2W, ±10%	800086	
R804,817, 820	Resistor, Fixed, Comp., 4.3K, 1/2W, ±5%	800621	

(Continued)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.7	500050	
R806	Resistor, Fixed, Comp., 5.6K, 1/2W,±5%	800641	
R807	Resistor, Fixed, Dep. Carb., 51K, 1/4W, ±1%	802252	
R808	Resistor, Fixed, Comp., 3.9K, 1/2W,±5%	800610	
R809	Resistor, Fixed, Dep. Carb., 47K, 1/4W ±1%	802251	
R812,813, 833,836	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R815,825	Resistor, Fixed, Comp., 68K, 1/2W,±5%	800528	
R816,821	Resistor, Fixed, Comp., 10K, 1/2W,±10%	800089	
R826,829 830,931	Resistor, Fixed, Comp., 110K, 1/2W, ±5%	800682	
R818,819	Resistor, Fixed, Comp., 22M, 1/2W,±10%	801754	
R827,828	Resistor, Fixed, Comp., 470Ω, 1/2W, ±10%	800084	
R834,835	Resistor, Fixed, Comp., 68Ω, 1/2W,±5%	801139	
R838,847, 850	Resistor, Fixed, Dep. Carb., 120Ω, 1/4W, ±1%	802250	
R839,842	Resistor, Fixed, Comp., 24K, 2W, ±5%	802246	
R840,841	Resistor, Fixed, Dep. Carb., 5.6K, 1/4W, ±1%	802247	
R843,844	Resistor, Fixed, Dep. Carb., 1.5K, 1/4W, ±1%	802248	

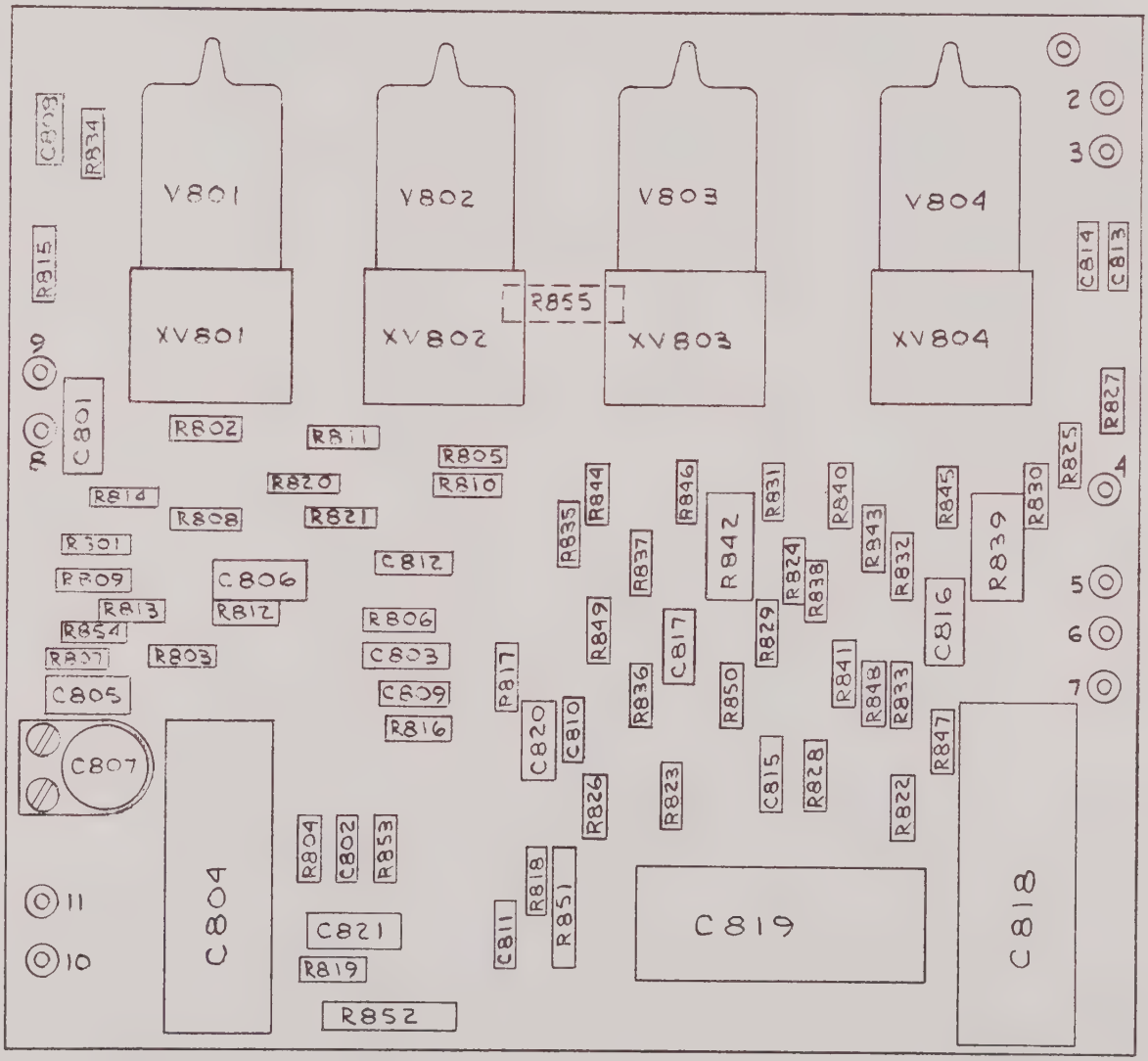
(Continued)

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.7	500050	
R845,846	Resistor, Fixed, Comp., 56K, 1/2W,±5%	800857	
R848,849	Resistor, Fixed, Dep. Carb., 910Ω, 1/4W, ±1%	802249	
R851,852	Resistor, Fixed, Dep. Carb., 10M, 1W, ±1%	802253	
R853	Resistor, Fixed, Comp., 22K, 1/2W,±10%	800155	
R854	Resistor, Fixed, Comp., 200K, 1/2w, ±10%	801873	
R855	Resistor, Fixed, W.W. 0.56Ω, 2W, ±10%	802399	
V801,802	Tube, Electron, 6U8	800028	
V803,V804	Tube, Electron, 6AN8	801521	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



REF. DRIVE AMPL. ASSY.
500050

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.8	500083	
*C901	Capacitor, Fixed, 20ufd, 350V	800847	Used as input
*C902	Capacitor, Fixed, 30ufd, 250V	801528	cap. with
*C903,904 905	Capacitor, Fixed, 20ufd, 250V	801221	silicon rect-ifier.
C905	Capacitor, Fixed, .0022ufd, 400V,±10%	802240	
C906	Capacitor, Fixed, .01ufd, 200V, ±10%	801879	
C907	Capacitor, Fixed, 24uufd, 500V, ±5%	802216	
C908	Capacitor, Fixed, .33ufd, 200V, ±10%	801527	
C910	Capacitor, Fixed, 450V, 20ufd,	801222	
C911	Capacitor, Fixed, 100uufd, 200V, ±10%	801264	
C913	Capacitor, Fixed, .001ufd, 200V, ±10%	802218	
C914	Capacitor, Fixed, 150uufd, 500V, ±5%	801365	
C915	Capacitor, Fixed, 4ufd, 350V	800888	
C916	Capacitor, Fixed, 10ufd, 50V	802209	
CR901,902	Diode, SR200	800985	Sylvania
CR903,904	Diode, IN2071	800986	
CR905,906	Diode, IN1692	800987	G.E.
DS902	Lamp, Neon, NE76	801523	
Q901	Transistor, TR650	801522	
Q902	Transistor, 2N398	801520	

(Continued)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
Q903	Transistor, 2N1539	802441	
Q904,906	Transistor, 2N1381	800872	
Q906	Transistor, 2N495	802498	Texas Instrument
R901,902, 910,916	Resistor, Fixed, Comp., 22Ω, 1/2W, ±10%	800988	
R903,R904	Resistor, Fixed, WW, 2.5K, 3W, ±5%	802374	
R905	Resistor, Fixed, Metal Film, 160K, 1/2W, ±1%	802347	
R906	Resistor, Fixed, Metal Film, 82K, 1/2W, ±1%	802348	
R907	Resistor, Fixed, Comp., 270K, 1/2W, ±10%	800059	
R908**	Resistor, Fixed, Comp., 27K, 1/2W, ±10%	800088	
R909	Resistor, Fixed, Comp., 430 , 1/2W, ±5%	800640	
R911	Resistor, Fixed, Comp., 160K, 1/2W, ±5%	800859	
R912**	Resistor, Fixed, Comp., 33K, 1/2W, ±10%	800839	
R913	Resistor, Fixed, Comp., 100K, 1/2W, ±10%	800086	
R914	Resistor, Fixed, Comp., 470K, 1/2W, ±10%	800060	
R915	Resistor, Fixed, Comp., 2.7Ω, 1W, ±10%	801738	
R917	Resistor, Fixed, WW, 25Ω, 3W, ±5%	800075	
R918	Resistor, Fixed, WW, 5K, 7W, ±10%	802463	
R919	Resistor, Fixed, Metal Film, 35K, 1/4W, ±1%	802543	
R920	Resistor, Fixed, Comp., 36K, 1/2W, ±5%	801016	

** Nominal value - trimmed at test.

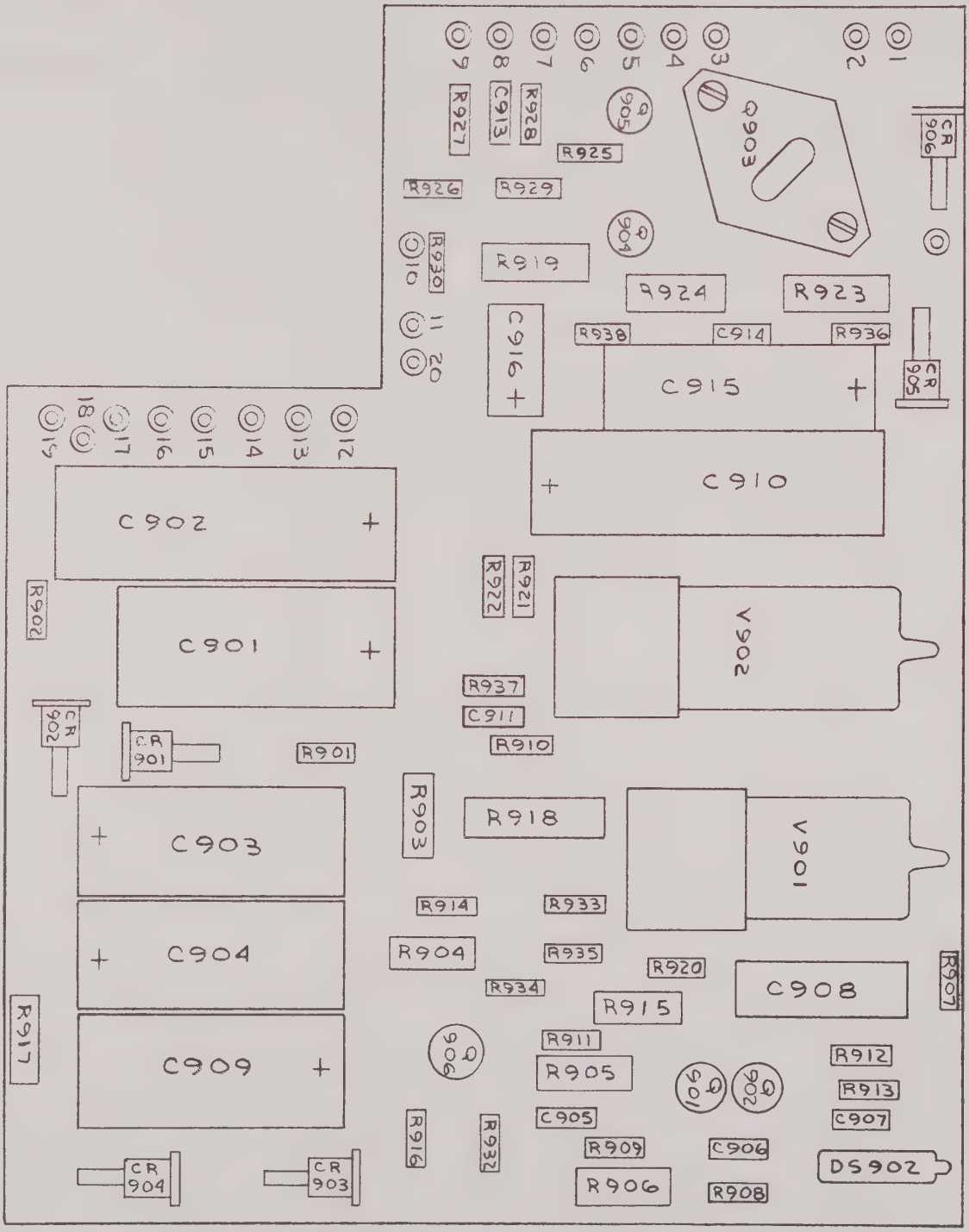
NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.8	500083	
R921	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R922,929	Resistor, Fixed, Comp., 220K, 1/2W, ±10%	800058	
R923	Resistor, Fixed, Metal Film, 218K, 1/2W ±1%	802210	
R924	Resistor, Fixed, Metal Film, 14K, 1/2W, ±1%	802439	
R925	Resistor, Fixed, Comp., 4.7K, 1/2W, ±10%	800078	
R926	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R927	Resistor, Fixed, Comp., 150Ω, 1/2W, ±5%	801140	
R928	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R930**	Resistor, Fixed, Comp., 39K, 1/2W, ±10%	801069	
R932	Resistor, Fixed, Comp,, 30K, 1/2W, ±5%	800622	
R933	Resistor, Fixed, Comp., 1.5M, 1/2W, ±5%	802214	
R934	Resistor, Fixed, Comp., 150K, 1/2W, ±5%	800856	
R935	Resistor, Fixed, Comp., 270K, 1/2W, ±5%	802213	
R936	Resistor, Fixed, Comp., 110Ω, 1/2W, ±5%	801145	
R937**	Resistor, Fixed, Comp., 240K, 1/2W, ±5%	801282	
R939**	Resistor, Fixed, Comp., 1.8K, 1/2W, ±5%	800858	
V901	Tube, Electron, 7AN8	801521	
V902	Tube, Electron, 12B4A	800973	
**Nominal	value - trimmed at test.		

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



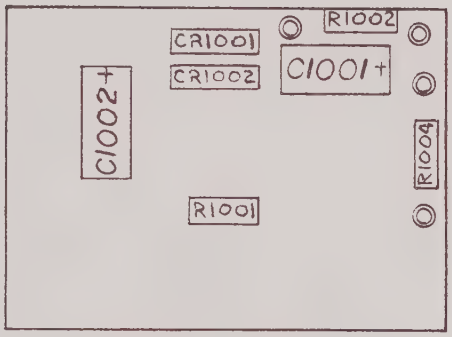
POWER SUPPLY TERMINAL BOARD ASSY.
500083

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Meter Board - Figure 4.9	500181	
C1001, 1002	Capacitor, Fixed, 50ufd, 6V	800163	
CR1001, 1002	Ciode, IN461	800942	Clevite
R1001	Resistor, Fixed, Comp., 10Ω,1/2W,±10%	801518	
R1002	Resistor, Fixed, Comp., 820 , 1/2W,±10%	800082	
R1004	Resistor, Fixed, Comp., 2.2K,1/2W,±10%	800829	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



METERBOARD ASSY.
500181

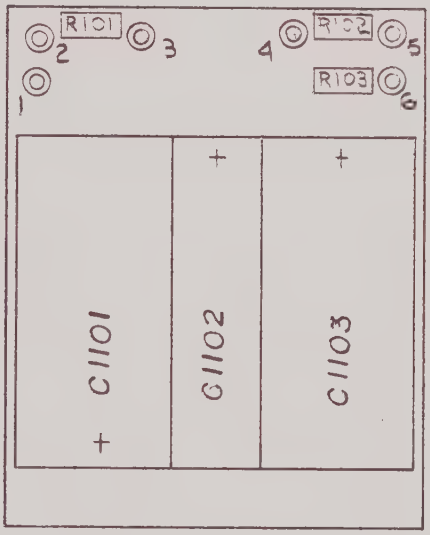
NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Decoupling Board Figure 4.10	500177	
C1101	Capacitor, Fixed, 40ufd, 150V	800983	
C1102	Capacitor, Fixed, 4ufd, 350V	800888	
R1101	Resistor, Fixed, Comp., 4.7K,1/2W,±10%	800847	
R1102,1103	Resistor, Fixed, Comp., 56K,1/2W, ±5%	800857	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



SIG. DE-COUPLING BOARD ASSY.
500177

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

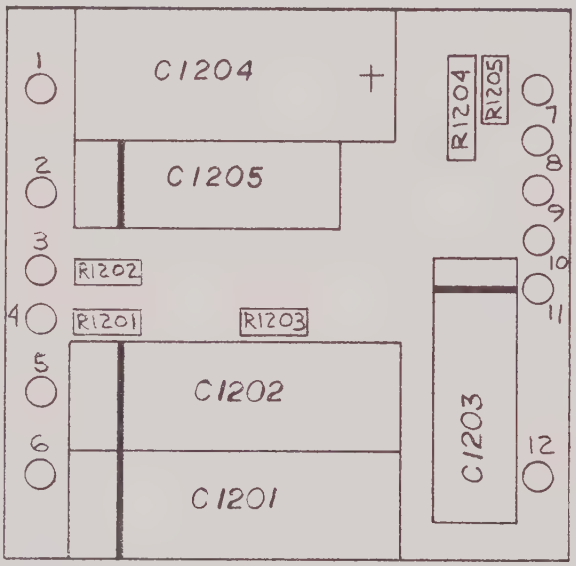
REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Filter and Overload Figure 4.11	500276	
C1201,1202	Capacitor, Fixed, 22ufd, 400V, ±20%	801604	
C1203,1205	Capacitor, Fixed, .1ufd, 400V, ±20%	800020	
C1204	Capacitor, Fixed, 20ufd, 350V	800847	
R1201	Resistor, Fixed, Comp., 270K,1/2W,±10%	800059	
R1202	Resistor, Fixed, Comp., 91K, 1/2W, ±5%	802142	
R1203	Resistor, Fixed, Comp., 2.2K,1/2W,±5%	800079	
R1204	Resistor, Fixed, Dep. Carb., 10K, 1/2W, ±1%	801481	
R1205	Resistor, Fixed, Comp., 10M,1/2W, ±10%	801025	

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. *overbrook 1-8600*



SIGNAL FILTER & OVERLOAD ASSY.
500276

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	500229	
C1301	Capacitor, Variable, 3012uufd	801512	
C1302	Capacitor, Variable, 5025uufd	801483	
C1303	Capacitor, Fixed, .lufd, 1000V, ±10%	801068	
C1304	Capacitor, Fixed, .027ufd, 100V ± 5 %	802571	
C1305	Capacitor, Fixed, 3.9uufd, 500V, ±5%	802163	
C1306	Capacitor, Fixed, 43uufd, ±2%	802446	
C1307	Capacitor, Fixed, 150uufd, ±2%	802447	
C1308	Capacitor, Fixed, 220uufd, ±5%	802448	
C1309	Capacitor, Fixed, 250uufd, ±5%	802449	
C1310	Capacitor, Fixed, 300uufd, ±5%	802450	
C1311,1314, 1315,1316 1312,1313	Capacitor, Fixed, .lufd, 200V,±10%	802220	
C1317	Capacitor, Fixed, 22ufd, ±5%	802572	
CR1301, 1302	Diode, IN658	801661	
R1301	Resistor, Fixed, Metal Film, 10M, 1/2W, ±1/2%	802516	
R1302	Resistor, Fixed, Metal Film, 10K, 1/2W, ±1/4%	802517	
R1303	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R1304	Resistor, Fixed, Comp., 120Ω, 1/2W, ±5%	800407	
R1305	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	

(Continued)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	500229	
R1306	Resistor, Fixed, Metal Film, 6.84K, 1/8W, ±1/4%	801474	
R1307	Resistor, Fixed, Metal Film, 2.16K, 1/8W, ±1/4%	801475	
R1308	Resistor, Fixed, Metal Film, 684Ω, 1/8W, 1/4%	801476	
R1309	Resistor, Fixed, Metal Film, 216Ω, 1/8W, 1/4%	801477	
R1310	Resistor, Fixed, Metal Film, 68.4Ω, 1/8W, 1/4%	801478	
R1311	Resistor, Fixed, Metal Film, 31.6Ω, 1/8W, 1/4%	801479	
R1312,1313, 1314,1315, 1316,1317	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	
R1318	Resistor, Fixed, W.W., 0.56Ω, 2W, ±10%	802399	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
C102	Capacitor, Fixed, 22uufd, 500V, ±5%	802164	
C103	Capacitor, Fixed, .1ufd, 200V, ±10%	802220	
R105	Resistor, Variable, 5K, 1/2W	802472	
R107	Resistor, Fixed, Dep. Carb., 5K, ±1%	801166	
R108	Resistor, Fixed, Dep. Carb., 7.5K, ±1%	802562	
R109,110	Resistor, Fixed, Comp., 10M, ±5%	801482	
R242	Resistor, Variable, 250Ω, 1/2W	801471	
C313	Capacitor, Fixed, 3.9uufd, 500V, ±5%	802163	
C314	Capacitor, Fixed, 200uufd, 500V, ±5%	802168	
C315	Capacitor, Fixed, 110uufd, 500V, ±5%	802559	
C316	Capacitor, Fixed, 150uufd, 500V, ±5%	802447	
C317	Capacitor, Fixed, 160uufd, 500V, ±5%	802560	
R318	Resistor, Fixed, Dep.Carb., 10K,1/2W,±1%	801481	
R320	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R321	Resistor, Variable, 2K (tapped, special)	801613	
R322	Resistor, Fixed, Comp., 56Ω,1/2W, ±5%	800653	
R505	Resistor, Variable, 1.5K, 2W	801470	
R608	Resistor, Fixed, Comp., 18K, 1/2W,±5%	800611	
R633	Resistor, Variable, Comp., 100Ω, 2W	801446	
R643	Resistor, Fixed, Comp., 200Ω,1/2W,±5%	801672	
T601	Transformer, Driver, Lo Freq.	200612	
T602	Transformer, Driver, Hi Freq.	200611	
C912	Capacitor, Fixed, 100ufd, 25V	800982	
T901	Transformer, Power	200688	

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
M1001	Meter Assembly	500162	
R1003	Resistor, Variable, 50K, 2W	800006	
XDS3,XDS4	Lampholder	801466	
DS3,DS4	Lamp, Phase Angle Dial	800093	
DS1201	Lamp, Overload	800532	
XDS1201	Lampholder	800397	
Group I	Phase Network Module	200719-1	NAI
Group 2	Phase Network Module	200719-2	NAI
Group 3	Phase Network Module	200719-3	NAI
Group 4	Phase Network Module	200719-4	NAI
B1	Fan, Cooling	802494	Rotron
S5	Switch, Toggle, Ref. Hi-Lo	800112	
S8	Switch Toggle, Power On-Off	800004	
F1	Fuse, 2 Amp, 2AG	800935	
XF1	Fuseholder	800137	
S2	Switch Lever Zero	500300	NAI
S7	Switch, Lever, Equal	801367	
	Knob, Round, Phase Dial	200812	NAI
	Knob, Round, Ref. Level, Equal, Zero, Phase Dial	801760	

(Continued) 4.43

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Knob, Pointer, Filter In/Out, Range, Function	801761	
	Knob, Pointer, Frequency	801762	
	Lens, Magnifying	801445	NAI
	Bezel, (for lens)	200308	
	Planetary Drive	200814	Waldom
	Dial Assembly, Phase Angle	500163	NAI
	Dial Indicator, Sub Assembly, Phase Angle	500318	
	Dial Assembly, Frequency Switch	500137	
	Dial Cover, Frequency Switch	200789	
S3A	Switch Filter	801473-2	
S3B	Switch, Filter	801473-1	
	Coupling Assembly, Filter Switch	500327	
	Actuator, Filter Switch	500189	
	Shaft, Filter Switch	200736	
	Bearing, Panel, Filter Switch	800727	
	Nut, Knurled, Filter Hold down	801809	
	Plate, Filter Hold down	201156	
	Post, Binding (Red)	800119	
	Post, Binding (Black)	800120	
	Mount, Binding Post	800121	
	Post, Ground	800546	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration or setting up of instrument.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

SECTION V

CHECKOUT AND ALIGNMENT PROCEDURE

TEST EQUIPMENT REQUIRED:

1.	AC VTVM	-	Ballantine 300H or equivalent
2.	Audio Signal Generator	-	Hewlett Packard 200CD or 650A, or equal.
3.	Phase Standard	-	Capable of generating:
			a. $90^{o} \pm .05^{o}$ from 10 cps to 100KC.
			b. $45^{o} \pm .05^{o}$ at 1KC.
4.	Attenuator	-	Kay Electric 31-0 or equivalent.
5.	Power Amplifier	-	Khronhite DC 10A, or equal.
6.	Multitester	-	Triplett 630 or equal.

Initial Ground Check

Check for stray ground path. Should read OPEN (no reading on Multitester X100,000 Range) from signal ground (Black terminal post) to chassis (metal terminal post).

Initial Power Supply Voltage Check

A. Short reference and signal input terminals. Short signal ground post and chassis (metal post).

B. Third prong on power plug should be connected to a house ground.

C. Apply power to Phase Angle Voltmeter. Observe that filaments and pilot light are on. Make sure that neon

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

light on power supply ignites within a minute.

D. All instruments have been carefully factory inspected and calibrated. The instruments should have an output between the limits listed below in DC VOLTS and an AC ripple level below that listed.

PIN	DC VOLTS	AC VTVM
10	-79 to -81	Approx. 200uv
11	+255 to +265	Approx. 1MV
12	+175 to +200	High 10-20 volts
15	+260 to +270	Approx. 90MV
7	-12 to -12.6	Approx. 3MV
8	Ground (Tied to Signal Ground in Signal Amp.)	
16	-135	Approx. 150MV

Due to tube ageing, etc. the instrument may not remain within the above limits, and adjustment should be made. The appropriate controls for each output are listed below. The DC amplitude adjust noted is to be used to raise the DC voltage level. The AC ripple adjust noted is to be used to lower the particular ripple level.

DC AMPLITUDE ADJUST	RIPPLE ADJUST
R908 (27K Nom.)	R912 (33K Nom.)
R939 (1.8K Nom.)	R937 (130K Nom.)
No Adj.	No Adj.
No Adj.	No Adj.
R930 (39K Nom.)	No Adj.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

Voltage Range Adjustment (Low Range)

The purpose of this adjustment is to calibrate the full scale voltage sensitivity of the signal channel. This calibration will adjust the sensitivity of the 1MV to 300MV set of ranges.

A. Connect Signal Generator to an AC VTVM and input of the attenuator.

B. Connect output of attenuator to input of VM-301.

C. Switch Function Switch to VTVM (VM-301).
Switch Filter Switch to OUT (VM-301).

D. Adjust Signal Generator to 1KC and 1 volt output.

E. Set attenuator to 100 millivolts output.

F. Set Range Switch to 100 millivolts range and adjust calibrate potentiometer R242 on back panel for exactly 100 millivolts on voltmeter (VM-301).

G. In steps corresponding to the Range Switch steps, check all ranges from 1MV to .3 volts.

H. Repeat Steps A through G at 10~, 100~, 10KC, 50KC, and 100KC.

NOTE: All readings should be within ±2% from 10~ to 100KC.

Reference Pre-Amp Adjustment

(This should be done any time Tube V-301 is changed.)

This will adjust the DC voltage across the "Reference Adjust" potentiometer to zero and ensure smooth operation of this control.

Adjust DC voltage on Pin 16 of D-500096 (Reference Pre-Amp) to equal zero with R309.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

Reference Channel Sensitivity

This procedure is to ensure proper reference sensitivity.

A. Adjust signal generator to 1000~ and approximately .3 volts output.

B. Short signal input (VM-301).

C. Switch Frequency Switch to "CPS" and "316 to 1000."
Switch Function Switch to "0" degrees.
Switch Filter Switch to "OUT."
Switch Reference Level Switch to "LO."

D. Adjust reference level pot to give approximately half scale reading on Reference Level Meter.

E. Decrease signal input, slowly readjusting Reference Level control to keep pointer of Reference Level Meter on scale. The pointer should be on scale until input is reduced to approximately .14 volts input.

Common Mode Adjustments

This procedure will balance the push-pull output voltage of the Reference Drive Amplifier so that the meter will read a null with a normal reference input and zero signal input. This balance will be done in the mid-band of frequencies and at 100KC.

A. Repeat Steps A to D of Paragraph 5.

B. Meter should read ±2uv independent of Range Switch or phase sensitive position of Function Switch. If this reading is exceeded, adjust R847 or R850 as required for a null.

C. Adjust signal generator to 100KC and repeat A through D of Paragraph 5. Note that Frequency Switch should be on "KC" and "31.6-100."

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. overbrook 1-8600

D. Short either side of L202 on Signal Amplifier to circuit ground. Adjust C807 on Reference Drive Amplifier for an approximate null.

E. Remove short on L202 of Signal Amplifier. Add trimmer capacitor (5-15uuf) from Pin 2 of V804 or V803 (as required) to circuit ground trimming for an accurate null.

F. Repeat Step D.

ZERO-EQUAL Control Operations

Before continuing further with the tests, review the following points:

A. Whenever phase sensitive measurements are being made, it is necessary to zero equal the Model VM-301 each time the frequency is changed. This is necessary in the following test and should be done when the frequency is changed. This will be referred to as "EQUAL" or "ZERO."

B. EQUAL: This is done by adjusting the Reference Signal Level to obtain an on scale reading on the Reference Level Meter. Depress the EQUAL Switch and adjust the EQUAL control so that there is no change in reference level when the EQUAL Switch is normal or depressed.

C. ZERO: Depress the ZERO Switch and adjust the Zero control to read a null on the voltmeter.

ZERO Switch Adjustment

Filter Out

This procedure will ensure that depressing the ZERO Switch will insert into the signal channel a voltage

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

having the same phase as the reference. This is done by adjustment of the broadband attenuator which samples the reference signal.

A. Connect signal generator output to reference and signal terminals.

B. Set Function Switch to "0°."

C. Set Filter Switch to "OUT."

D. Set Range Switch to 1.0 volts.

E. Set Frequency Switch to "KC" and 3.16 to 10KC.

F. Set signal generator to 8KC, and adjust output (no attenuation) to .6 volts. Set Range Switch to .1 volts (6x overload).

G. Set Reference Level Switch to "LO," and adjust Reference Level Potentiometer to give approximately half-scale reading on Reference Meter.

H. Switch Function Switch to 90°. Meter will read approximately a null.

I. Adjust "ZERO" Control for a null without depressing the "ZERO" switch.

J. Depress "ZERO" Switch, and adjust C308 for a null. (See Figure 5.2).

Filter-In Position

K. Place short circuit into filter sockets between Pins 2 and 8 of the octal socket.

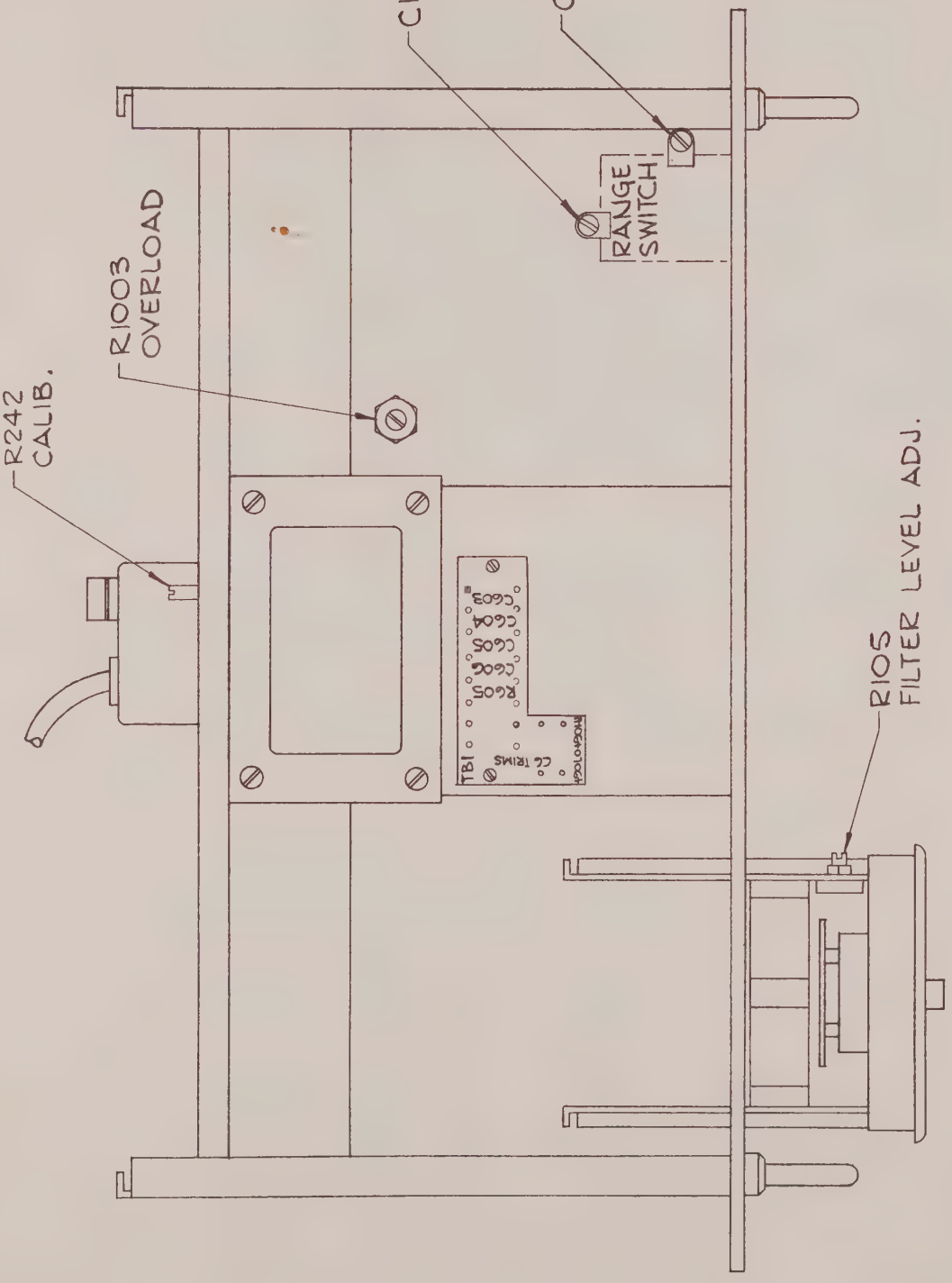
L. Switch to filter "IN" position.

M. Adjust "ZERO" control for a null without depressing the "ZERO" Switch.

N. Depress "ZERO" Switch and trim capacitor C102 on grid.

These instrument changes are valid from Instrument Serial No. 5294, (4-6-64).

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600



TOP VIEW

Figure 5.1

NORTH ATLANTIC industries, inc.
terminal drive, plainview, l. i., n. y., overbrook 1-8600

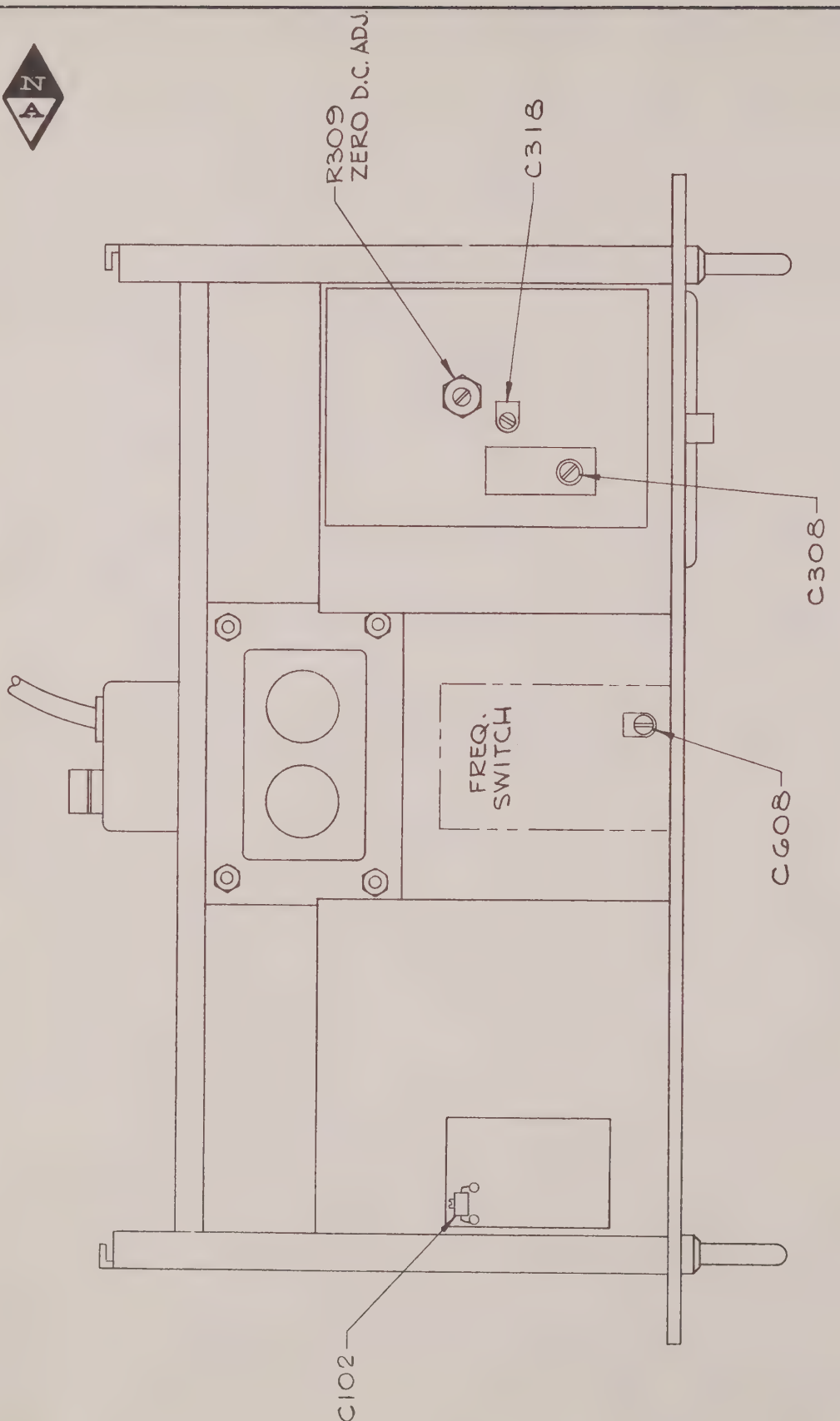


FIGURE 5.2

BOTTOM VIEW

NORTH ATLANTIC *industries, inc.*

terminal drive, plainview, l. i., n. y., overbrook 1-8600

of filter in signal pre-amplifier V102 for a null (See Figure 5.2).

10~ and 100KC Adjustment

O. Repeat Steps A to H at 100KC and 10~ with Frequency Switch in the appropriate position.

P. Depress "ZERO" Switch and adjust "ZERO" control for a null. Release "ZERO" Switch. Trim out offset, if any, at 10~ by placing a high value resistor (5 to 30 meg.) across input to signal or reference amplifier. Trim out effect, if any, at 100KC by placing a capacitor (nom. 50uuf) from the cathode of V101 or V301 to ground.

Reference Hi-Lo Attenuator

This procedure will adjust the 30:1 reference input attenuator so that there is no phase difference between the HI or LO positions of the Reference Input Switch.

A. Set Frequency Switch to "KC" and "1-3.16KC" position.
Set Reference Level control full counter-clockwise.
Set Function Selector to 90° position.
Set Range Switch to 1 volt range.
Set Filter IN-OUT Switch to "OUT" position.

B. Set generator to 1.6KC. Adjust output to give approximately half-scale reading on the Reference Level Meter.

C. Null the meter with the "ZERO" control without depressing "ZERO" Switch.

D. Switch Reference HI-LO Switch to "HI" and turn Reference Level Control full clockwise. This should result in an on-scale reading of the Reference Level Meter.

E. Adjust C318 on Reference Preamplifier for a null on the voltmeter (VM-301).

High Signal Range Adjustment

This procedure will adjust the 1000:1 signal input attenuator so that the attenuation is correct at all frequencies, and there is no phase shift across the attenuator.

A. Set Frequency Switch to "CPS" and"316 - 1000."

B. Set Range Switch to 3 volts.

C. Set Function Switch to 0°.

D. Set Reference Switch to appropriate position.

E. Adjust signal generator to 600~ and full scale output reading on meter (VM-301).

F. Adjust Reference Level Potentiometer to give approximately half-scale reading on Reference Meter.

G. Adjust attenuator to give 3 millivolt output. Switch Range Switch to 1 millivolt position (3X overload).

H. Switch Function Switch to "90°" position.

I. Null the VM-301 with the ZERO Control without depressing ZERO Switch.

J. Switch Range Switch to 1 volt position and remove attenuation from signal channel.

K. Adjust C1301 mounted on Range Switch to bring voltmeter (VM-301) to a null.

Range Switch Arm Capacitive Trim

The purpose of this trim is to compensate for the difference in capacitance of the Range Switch arm at 100KC.

A. Set signal generator to 100KC and 1 volt output out of the attenuator.

B. Set Range Switch to 300MV range (3X overload).

NORTH ATLANTIC industries, inc.
terminal drive, plainview, l. i., n. y.; overbrook 1-8600

C. Set Frequency Switch to "KC" and "31.6 - 100."

D. Reference Level Switch to appropriate position, Reference Level Control for mid-scale on Reference Level Meter.

E. Set Function Switch to 90°.

F. Null VM-301 without depressing ZERO Switch.

G. Attenuate signal by 40db (10MV ouput).

H. Switch Range Switch to 3MV.

I. Null VM-301 with C1302.

Overload Adjustment

This procedure adjusts the overload so that it starts to blink at a 10X overload.

A. Set Function Switch to "0°."

B. Set Filter Switch to "OUT" position.

C. Set Range Switch to 10 millivolts.

D. Set Frequency Switch to 1 to 3.16 KC range.

E. Set Reference Switch to appropriate position and Reference Control for half-scale reading on Reference Level Meter.

F. Apply input signal of 100MV.

G. Adjust overload potentiometer (R1003) so that overload light just starts to blink.

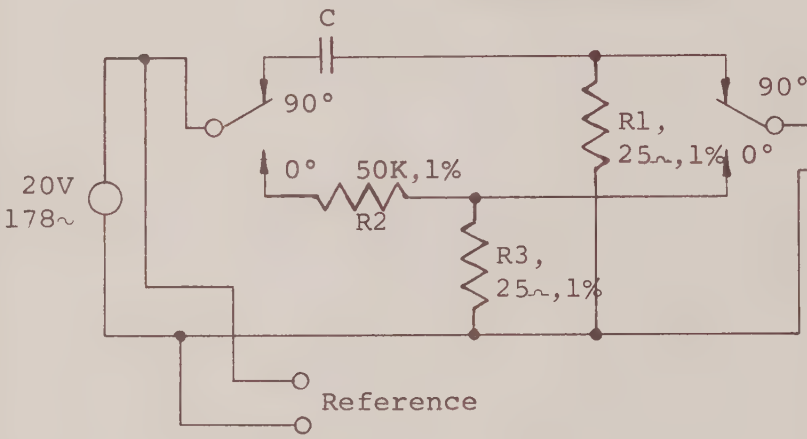
H. Compare input voltage causing light to blink vs. voltage drop causing the light to extinguish. (Both should occur at the same point at all frequencies, 10~, 500~, 10KC, 50KC, 100KC). It may be necessary to adjust

R229 of Signal Amp. Board for proper overload indication at 10~.

Phase Network Alignment

The purpose of this alignment is to calibrate the 90° phase shifters in the VM-301. In order to do this, it is necessary to have precision 90° sources available at the various frequencies corresponding to the networks being trimmed. A simple circuit for generating this at one frequency is shown below.

STANDARD NETWORK



C - See Table and Description Below

Tolerance: ±5%

R - See components on Schematic and description below.

Since this network will pass harmonics of the signal frequency with less attenuation than the signal frequency itself, C. must be a polystrene condenser with a dissipation factor of less than 0.02%. This will allow a phase shift to within 0.011° of 90°. Care must also be taken to reduce the capacity across R2 to a minimum. For this purpose, it would be wise to use two separate toggle switches as shown above. For example, 1 uuf across R2 can cause 0.18° of phase shift at 10KC. For this reason, it is also best to use metal film resistors.

The following table shows values of C for the frequencies of alignment.

BAND #	FREQ.BAND	FREQUENCY	C (STD NETWORK)	COMPONENT TO BE TRIMMED ON TB-1
2	31.6-100~	56.2~	.057 uf	C 604
3	100-316~	178~	.018 uf	C 605
4	316-1000~	562~	.0057 uf	C 606
5	1-3.16KC	1.78KC	.0018 uf	C 603
6	3.16-10KC	5.62KC	.00057 uf	R 605

The procedure for alignment is as follows:

A. Set Range Switch to 1MV position (10X overload).
Set Frequency Switch to appropriate position for frequency to be calibrated.
Set Filter In-Out Switch to "OUT" position.
Set Function Switch to 0° position.

B. Apply 20V (frequency to be calibrated) to the standard network and to the reference input terminals. Apply output of standard network to signal input terminals.

C. Set Reference Hi-Lo Switch to "HI" position and set reference Level Control to approximately mid-scale on the Reference Level Meter.

D. Set the Standard Switches to the 90° position.

E. Null voltmeter with ZERO Control without depressing ZERO Switch.

F. Switch Standard Switches to the 0° position, and the Function Switch of the VM-301 to 90° position.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

G. If Step F does not result in a null, then a trim component must be placed on the appropriate pins of TB-1, as shown in the above table, located on top of the phase module assembly. (See Figure 5.1).

H. This procedure must first be followed in Bands 2, 3, and 4, trimming C 604, C 605, C 606, respectively. Band 6 must then be trimmed with R 605. Finally Band 5 must be trimmed with C 603. The order for trimming must be followed carefully.

I. Other frequencies in each band may be checked by varying the value of R, so that the output amplitude of the phase standard is kept constant at 10MV level.

Special Phase Trim for Individual Band

The phase network alignment procedure described in the preceding section results in the alignment of the 90° networks on all frequency bands. It is noted that each of the calibrations is done at the geometric mean frequency of the frequency band being aligned and the variation within the band is generally less than 0.1°. It is also noted that bands 1, 7 and 8 are not trimmed at all. No trimming is necessary on these bands because trimming bands 2, 3, 4, 5 and 6 will automatically calibrate bands 1, 7 and 8. Due to the nature of the special networks and switching used, the calibration of one band will somewhat affect others.

In certain applications it may be desirable to calibrate a particular frequency or band without affecting the complementary band associated with it. Thus, the instrument has been designed to provide means for inserting a phase trim on any four of the eight bands, provided that the ones trimmed are not complementary. That is, either bands 1 or 5, 2 or 6, 3 or 7 and 4 or 8. If the instrument is so calibrated (by request) the procedure for changing or re-adjusting this trim follows.

It will be noted that terminal board TB-1 (see Fig 5.1) used for the phase network trim capacitors, has ten extra pins, six of which are marked 1, 2, 3, 4, Hi 90 and Lo 90. These pins are connected by means of the frequency switch so as to

allow the special band trimming noted above.

NOTE: Before attempting this trim, re-read carefully Phase Network Alignment procedure in the preceding section. (Do not touch previous network trims).

1. Using the standard test network outlined above, select values of C and R1 that will give 10MV output and 90° phase shift at the desired frequency (or band) using band 1 (10~ to 31.6~) as an example.

2. Follow the alignment procedure outlined in the manual on Page 5.13 steps A through F.

3. To bring the VM301 to exact null, temporarily connect a capacitor or resistor as needed between Pin 1 on TB-1 and Lo 90.

4. After selecting the proper value in Step 3, permanently install this component between pin 1 on TB-1 and its adjacent unmarked pin. Wire a jumper from the unmarked pin to the pin marked Lo 90.

5. The procedure used in steps 3 and 4, above may be used in any of the bands using pins 1, 2, 3, or 4 and Lo 90 consecutively for trimming bands 1, 2, 3, 4 respectively.

6. The high bands are trimmed in the same manner except Hi 90 is used in place of Lo 90. Pins 1, 2, 3, or 4 may be used to trim bands 5, 6, 7 or 8, respectively.

Phase Potentiometer Trimming

This trim is necessary to compensate for the effects of capacity to ground on the phase potentiometer arm. This effect is a maximum when the Phase Dial is at 45°, and the frequency is at the upper end of the CPS or KC ranges.

A. Set the Frequency Switch to "CPS" and "316-1000."

Set Function Switch to 90°.
Set Filter In-out Switch to "OUT" position.

B. Set signal generator to 1000~, and connect it to reference terminals and through zero phase attenuator, (66db) to signal input. Adjust signal generator for 20V output.

C. Switch Range Switch to 1MV range (10X overload).

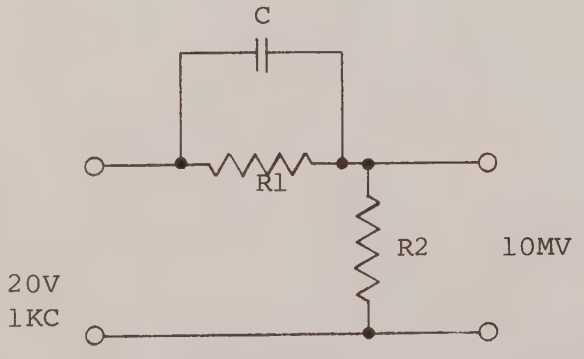
D. Set Reference Switch to "HI" and adjust reference level control for mid-scale reading on Reference Level Meter

E. Adjust "EQUAL" control as accurately as possible.

F. Adjust VM-301 for null with ZERO control without depressing ZERO switch.

G. Disconnect the signal generator from the attenuator, and connect it to an accurate 45° ±0.05 network, which has an output of 10MV. A network of this sort is shown below. Connect the output of this network to the signal input terminals.

H. Rotate Phase Dial to 45°, and adjust C608 for a null on the voltmeter.



C - .003 uf ±0.1% polystrene Dissipation factor is .02%.

R_1 - 53.11K, ±0.05% Metal Film.

R_2 - 22~ ±1% Metal Film.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

INSTRUCTION MANUAL SUPPLEMENT

VM-301

Patents are Pending for a Number of Circuits

Used in This Instrument

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

Copyright 1962, 1963, 1965 by North Atlantic Industries, Inc.

Printed in U.S.A.

INTRODUCTION

A number of improvements have been made in the Model VM-301 Phase Angle Voltmeter since the introduction of the instrument by North Atlantic Industries. These advances have been made in accordance with our basic policy of maintaining a constant program of product improvement to assure optimum reliability, maintainability, and performance of our instruments.

Prior to issuance of this supplement, the Instruction Manual shipped with each instrument did not record any of these changes. Since these product improvements have taken place over a period of time and this supplement has just become available, the logistics of determing the degree of modification of any individual instrument is extensive. The best and most rapid method of determination is visual examination of the individual circuit boards.

The majority of instruments presently in the field incorporate the changes presented in this supplement, which is intended only for maintenance and service.

Supplement #502

4-23-65

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

CONTENTS

A. This supplement includes Figure 2.1 (see Page 2.1) which was previously omitted from standard VM-301 Instruction Manuals, and a revised Page 5.2. For the user's convenience, it is recommended that these two pages, Figure 2.1 and the revised Page 5.2, be placed adjacent to the page it replaces in the original manual.

B. This supplement includes revisions to schematics, module outlines, component part locations, and replacement parts lists which are provided for maintenance and service only. This section is to be used in conjunction with the original manual.

> CAUTION: Do not attempt to modify any instrument to include revisions not presently in the instrument since there are, in many cases, changes in wire routing or critical location of components involved. Visual examination will reveal the revisions incorporated within the instrument, and will be a useful guide in the use of this supplement in conjunction with the original VM-301 Instruction Manual.

Supplement #502

4-23-65

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

light on power supply ignites within a minute.

D. All instruments have been carefully factory inspected and calibrated. The instruments should have an output between the limits listed below in DC VOLTS and an AC ripple level as listed below:

Pin	DC Volts	AC VTVM
10	-79 to -81	Approx. 600uv
11	+255 to +265	Approx. 1mv
12	+185 to +215	High 10-20 volts
15	+270 to +310	Approx. 90mv
7	+12 to +12.6	Approx. 3mv
8	Ground (Tied to Signal Ground in Signal Amp.)	
16	+120 to +135	Approx. 150mv

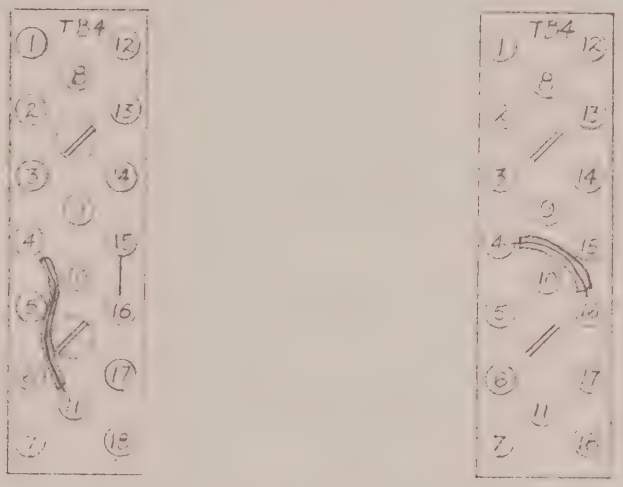
Due to tube ageing, etc., the instrument may not remain within the above limits, and adjustment should be made. The appropriate controls for each output are listed below. The DC amplitude adjust noted is to be used to raise the DC voltage level. The AC ripple adjust noted is to be used to lower the particular ripple level.

Pin	DC Amplitude Adj.	Ripple Adjust
10	R908 (27K Nom)	R912 (33K Nom)
11	R938 (1.8K Nom)	R937 (130K Nom)
7	R930 (39K Nom)	No adj.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

115V TO 230V CONVERSION

TOP VIEW



The conversion from 115V power connection (as wired at the factory) to 230V power connection is accomplished in the following manner (see sketches above):

1. Remove jumpers from Pins 4 to 11 and 15 to 16.

2. Add jumper from 4 to 16.

All connections between power input leads and power transformer primary windings are made to individual terminals on TB4. The above changes and the change of fuse F1 from 2 amp. to 1 amp. are all that is necessary to make this conversion. (TB4 is located below the power transformer on the back panel).

Figure 2.1

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Phase Angle Measurements - With Calibrated Phase Shifter

1. Adjust the Reference Channel as described in the Manual.

2. Set the Function Selector on "VTVM" position.

3. Set the Range Switch for maximum on-scale reading.

4. Set Phase Dial to "0 degrees" and the Function Selector to "0 degrees."

5. Set the Range Switch down to the next lower position.

6. A) Turn the Phase Dial for "0" meter reading (null). NOTE: If "0" reading cannot be obtained in this manner, proceed to Step 7.

7. Switch Function Selector to "90 degrees" and adjust Phase Dial for "0" meter reading.

8. Switch Function Selector to the position which results in a positive (up scale) reading.

9. The phase angle is the sum of the Function Selector setting <u>plus</u> the Phase Dial reading.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Phase Angle Measurements - With Calibrated Phase Shifter

1. Adjust the Reference Channel as described in the Manual.

2. Set the Function Selector on "VTVM" position.

3. Set the Range Switch for maximum on-scale reading.

4. Set Phase Dial to "0 degrees" and the Function Selector to "0 degrees."

5. Set the Range Switch down to the next lower position.

6. A) Turn the Phase Dial for "0" meter reading (null). NOTE: If "0" reading cannot be obtained in this manner, proceed to Step 7.

7. Switch Function Selector to "90 degrees" and adjust Phase Dial for "0" meter reading.

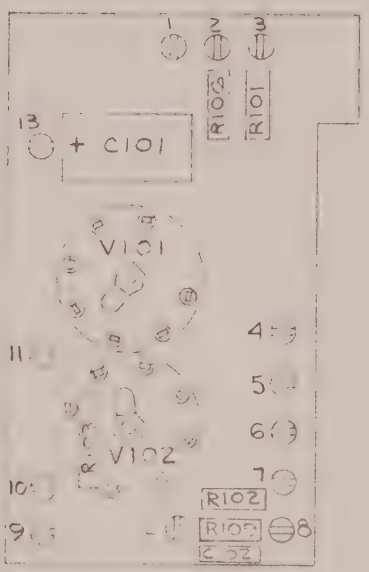
8. Switch Function Selector to the position which results in a positive (up scale) reading.

9. The phase angle is the sum of the Function Selector setting <u>plus</u> the Phase Dial reading.

Assembly, Signal Pre-Amplifier, NAI #C-500084
Figure 4.1, Page 4.4

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
			C102	Capacitor, Variable, 5-18uuf	802547	Added
R103	Resistor, Fixed, Dep. Carb., 3.2K	802564	R103	Resistor, Fixed, Dep. Carb., 2.5K, 1/2W, ±1%	802838	
R104	Resistor, Fixed, Comp., 75K, 1/2W, ±5%	800090				Deleted
			R109	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	Added

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n.y. (Voebrook 1-8600)



SIG. PRE-AMP BOARD ASSY.
500084

Figure 4.1

Assembly, Signal Amplifier, NAI #D-500047
Figure 4.2, Pages 4.6 - 4.9

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
C217,218	Capacitor, Fixed, .47uf 400V, ±10%	800866	C217,218	Capacitor, Fixed, .47uf 400V, ±10%	800025	
			C221	Capacitor, Fixed, .1uf, 200V	802220	Added
R234,235	Resistor, Fixed, Dep. Carb., 6.8K, 1/4W, ±1%	802464	R234,235	Resistor, Fixed, Dep. Carb., 6.8K, 1/4W, ±1%	802802	
			R247	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	Added
			R226	Resistor, Fixed, Comp., 33K, 1W, ±10%	802260	Omission
			V201,202, 203	Tube, Electron, 6BH6	802285	RCA Only
			V204	Tube, Electron, 6U8A	800028	Omission
R215	Resistor, Fixed, Comp., 2.2Meg, 1/2W	800064	R215	Resistor, Fixed, Comp., 4.3 Meg, 5%, 1/2W	803707	
R217	Resistor, Fixed, Comp., 10 Meg, 10%, 1/2W	801025	R217	Resistor, Fixed, Comp., 6.2Meg, 5%, 1/2W	803708	

Rev. A
3/2/66

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. (Overlook 1-8600)

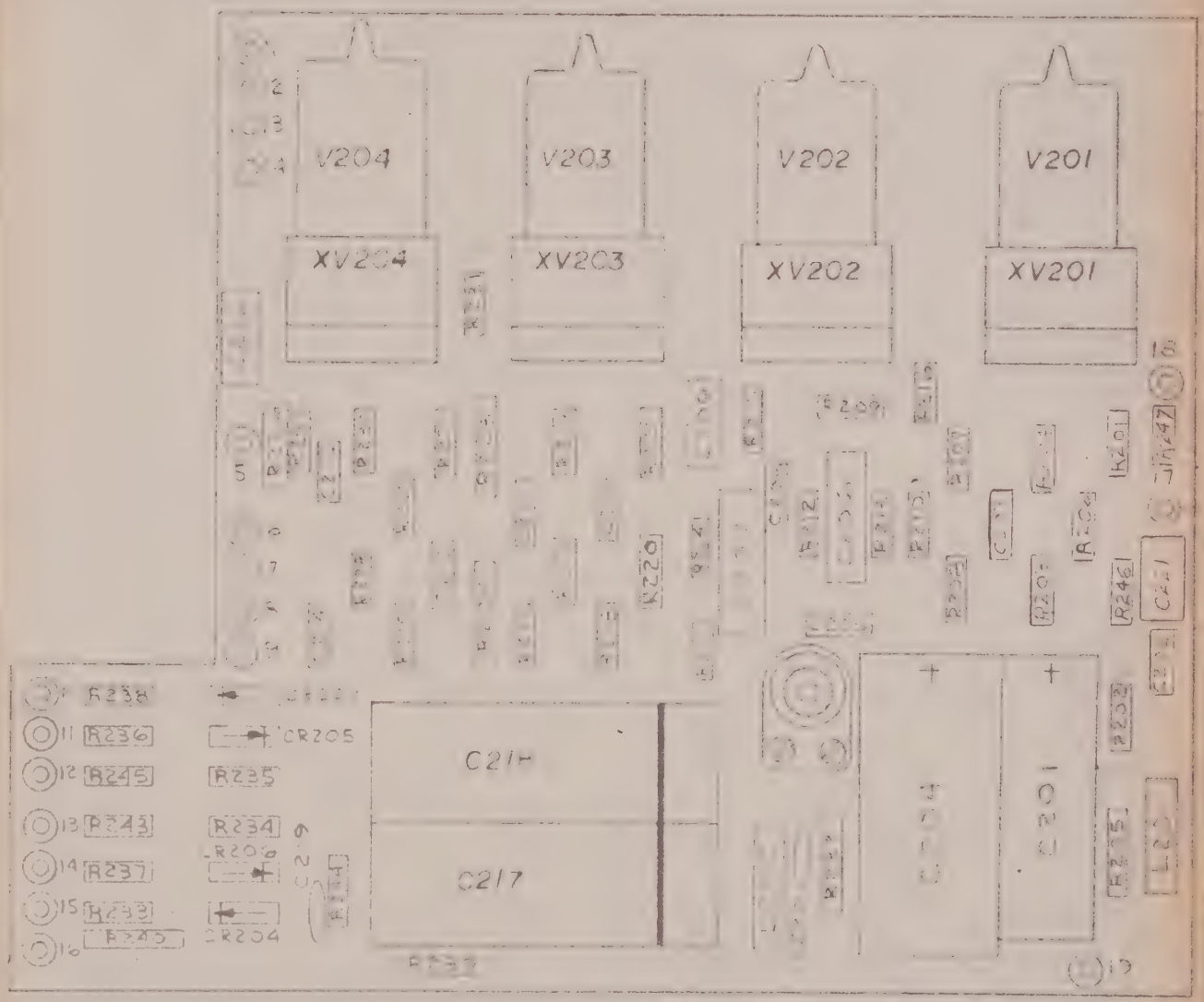
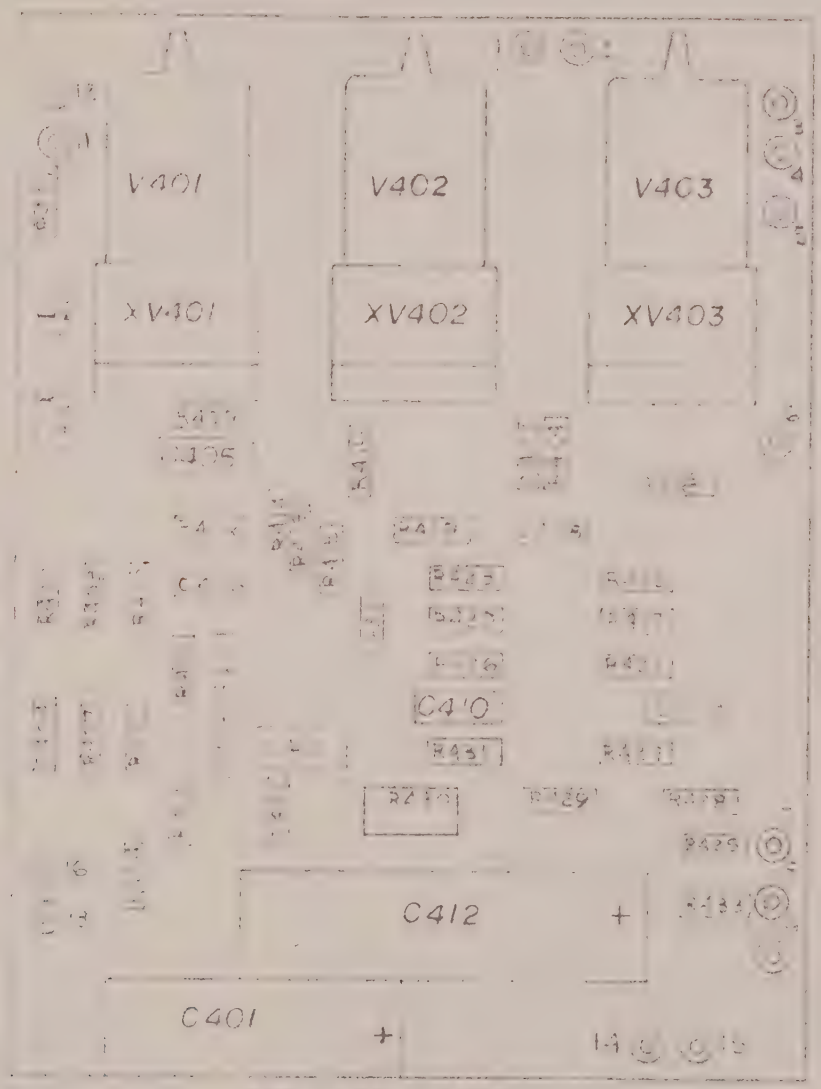

V204
V203
V202
V201
XV204
XV203
XV202
XV201
C217
C201
R238
R236
R245
R243
R237
R233
R235
R234
R232
CR205
CR204

Figure 4.2

Assembly, Reference Pre-Amplifier, NAI #D-500086
Figure 4.3, Page 4.11, 4.12

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
C302	Capacitor, Fixed, 330uuf, 200V, ±10%	802242	C302	Capacitor, Fixed, 300uuf, 200V, ±10%	802342	Special
C303	Capacitor, Fixed, 10uuf, 500V, ±5%	802561	C303	Capacitor, Fixed, 10uuf, 500V, ±5%	802628	Special
C307	Capacitor, Fixed, 10uuf, 500V, ±5%	802561	C307	Capacitor, Fixed, 20uuf, 500V, ±5%	802638	Special
C305	Capacitor, Fixed, .1uf, 400V, ±5%	802262	C305	Capacitor, Fixed, 1uf 200V, ±5%	802794	
R301	Resistor, Fixed, Dep. Carbon, 10M, 1W, ±1%	801507	R301	Resistor, Fixed, Metal Film, 10M, 1/2W, ±1%	802864	
R302	Resistor, Fixed, Dep. Car Carb., 300K, 1W, ±1%	801165	R302	Resistor, Fixed, Metal Film, 300K, 1/2W, ±1%	802865	
R308	Resistor, Fixed, Dep. Carb., 10M, 1/2W, ±1%	802253	R308	Resistor, Fixed, Metal Film, 1M, 1/2W, ±1%	802795	
R310	Resistor, Fixed, Dep. Carb., 300K, 1/2W, ±1%	801165	R310	Resistor, Fixed, Dep. Carb., 60K, 1/2W, ±1%	802796	
R311	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	R311	Resistor, Fixed, Comp., 20M, 1/2W, ±10%	801482	
R315	Resistor, Fixed, Dep. Carb., 3.2K, 1/2W, ±1%	802564	R315	Resistor, Fixed, Dep. Carb., 4.1K, 1/2W, ±1%	802172	

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
Assembly, Reference Amplifier Figure 4.4, Page 4.14		D-500049				
R433	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	R433	Resistor, Fixed, Comp., 1K, 1/2W, ±5%	800414	
R430	Resistor, Fixed, Comp., 43K, 1/2W, ±5%	801024	R430	Resistor, Fixed, Comp., 30K, 2W, ±5%	802828	
S6, Assembly, Frequency Switch Page 4.19, 4.20		500231				
R603	Resistor, Fixed, Comp., 2M, 1/2W, ±5%	802173				Deleted
R606	Resistor, Fixed, Dep. Carb., 602Ω, 1/4W, ±1/2%	801701	R606	Resistor, Fixed, Dep. Carb., 583Ω, 1/4W, ±1/2%	802585	
R611	Resistor, Fixed, Dep. Carb., 62.5K, 1/4W, ±1/2%	801709	R611	Resistor, Fixed, Dep. Carb., 60.5K, 1/4W, ±1/2%	802584	
			R650	Resistor, Fixed, Comp., 100K, 1/2W, ±5%	800520	Added



I.F. AMP. ASSY.
500049

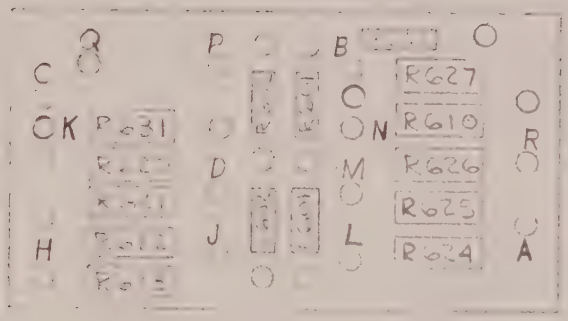
Figure 4.4

NORTH ATLANTIC industries inc
500 terminal drive, plainview, n.y.
S3

*Nominal value only, trimmed at test by selection of R603

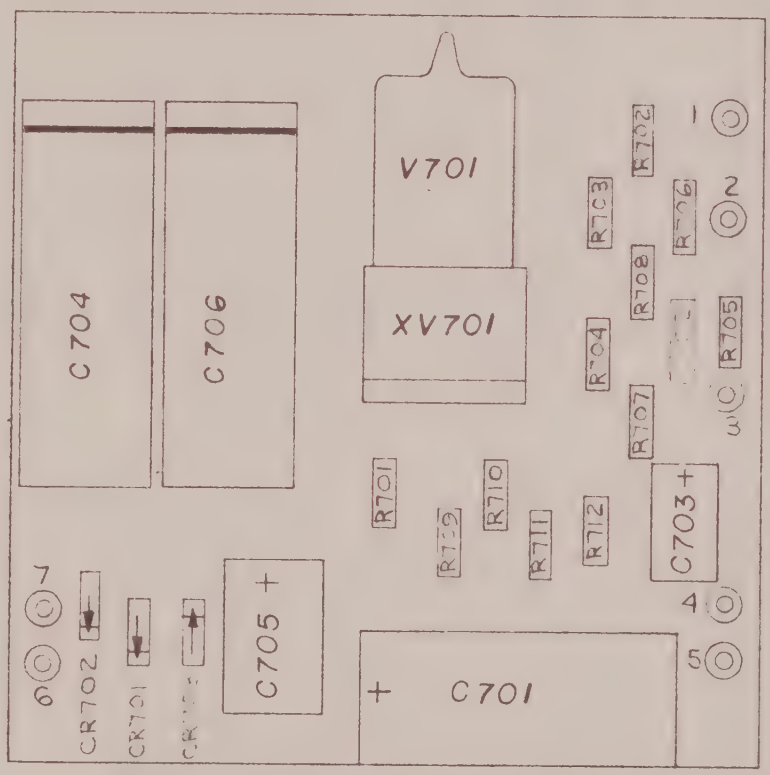
Circuit Ref	OLD Description	NAI Part No.	Circuit Ref	NEW Description	NAI Part No.	Remarks
TB6	Terminal Board Assembly Page 4.20, 4.21	500292				
R621,622	Resistor, Fixed, Dep. Carb., 470Ω, 1/4W, 1/4%	801699	R621,622	Resistor, Fixed, Dep. Carb., 158Ω, 1/4W, 1/4%	802763	
			R643	Resistor, Fixed, Comp., 200Ω, 1/2W, ±5%	801672	
R631	Resistor, Fixed, Dep. Carb., 117Ω, 1/4W, ±1%	801696	R631	Resistor, Fixed, Dep. Carb., 166Ω, 1/4W, 1/4%	802764	
TB3	Terminal Board Assembly Page 4.21	500298				
R628,630	Resistor, Fixed, Dep. Carb., 90.6K, 1/2W, ±1%	801514	R628,630	Resistor, Fixed, Dep. Carb., 90.6K, 1/2W, 1/4%	802786	
R638,641	Resistor, Fixed, Dep. Carb., 906Ω, 1/2W, ±1%	801513	R638,641	Resistor, Dep. Carb., Fixed, 906Ω, 1/2W, 1/4%	802785	
TB1	Terminal Board Assembly, Phase Network Module Trim Page 4.1	201433				
R605	Resistor, Select at Test	------	R605*	Resistor, Fixed, Comp., 24Ω, 1/2W, ±5%	800616	*Nom Value
			R603	Select at Test	------	Added
Assembly, Monitor Voltmeter Terminal Board, Figure 4.6 Page 4.23		500048				
R708	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	R708	Resistor, Fixed, Comp., 47Ω, 1/2W, ±5%	800555	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. (Overbrook 1-6600)



TERM. BOARD ASSY. (TI)
300092

Figure 4.5A



MONITOR VOLTMETER TERMINAL BOARD ASSY.
500048

Figure 4.6

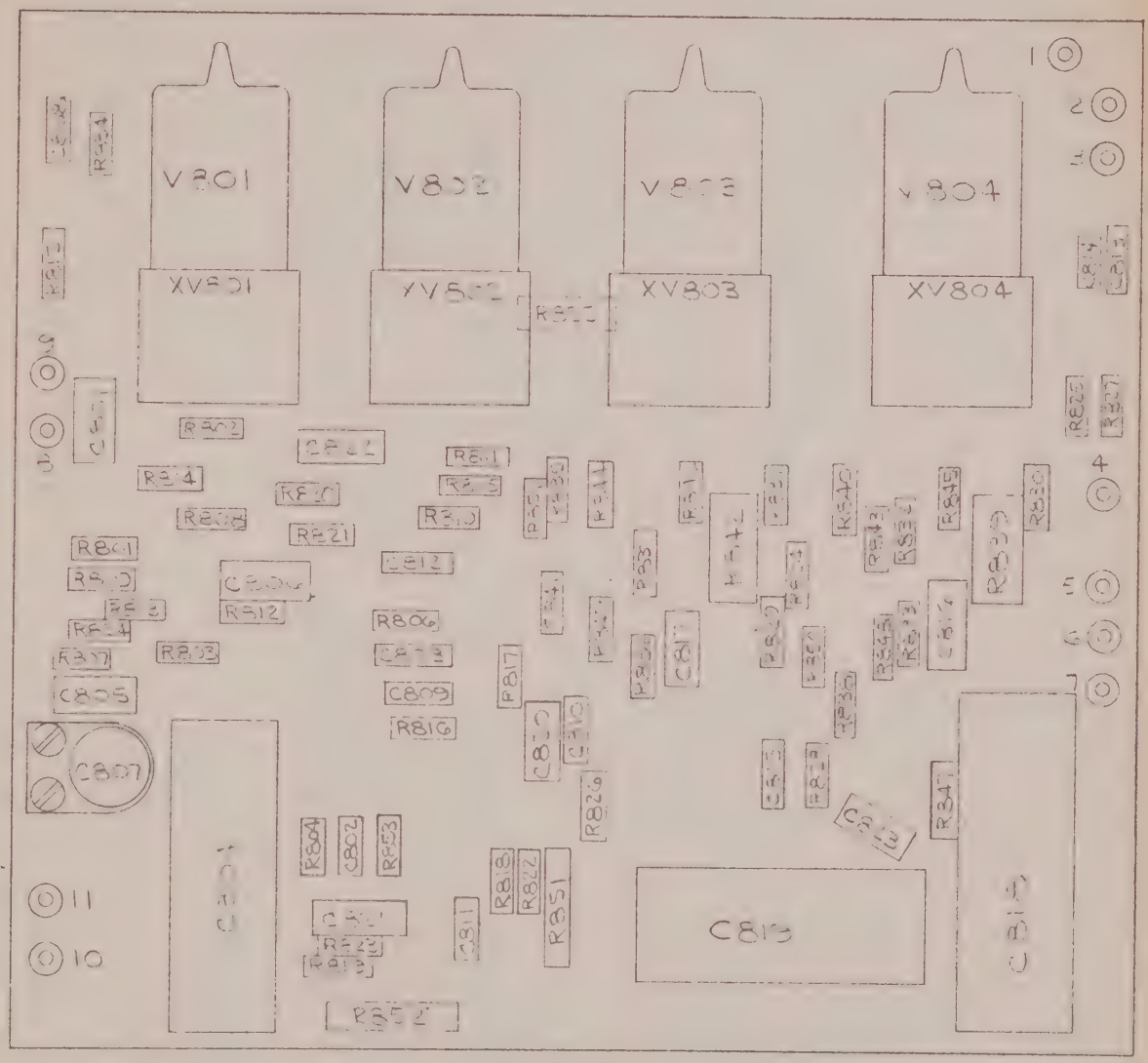
NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

Assembly, Reference Driver Amplifier, NAI #500050
Figure 4.7, Pages 4.26, 4.27

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
C801,805 806	Capacitor, Fixed, .1uf 200V, ± 10%	802220	C801,805, 806,816, 817,822	Capacitor, Fixed, .1uf 200V, ±10%	802220	C816,817 822 Added
C804	Capacitor, Fixed, 10uf, 250V	801227	C804	Capacitor, Fixed, 30uf 250V	802774	
C809,812	Capacitor, Fixed, .001uf 400V, ±10%	802241	C809,812	Capacitor, Fixed, .0018uf 400V, ±10%	802236	
C820,821	Capacitor, Fixed, .022uuf 400V, ±10%	802235	C820,821	Capacitor, Fixed, .022uf 400V, ±10%	802235	Error
			C823	Capacitor, Fixed, .22uf 100V	802863	Added
R807	Resistor, Fixed, Dep. Carb., 51K, 1/4W, ±1%	802252	R807	Resistor, Fixed, Dep. Carb., 10.4K, 1/4W, ±1%	802840	
R808	Resistor, Fixed, Comp., 3.9K, 1/2W, ±5%	800610	R808	Resistor, Fixed, Comp., 1K, 1/2W, ±5%	800414	
R809	Resistor, Fixed, Dep. Carb., 47K, 1/4W, ±1%	802251	R809	Resistor, Fixed, Dep. Carb., 9K, 1/4W, ±1%	802717	
R812	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	R812	Resistor, Fixed, Comp., 240K, 1/2W, ±5%	801282	
R813	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	R813,856	Resistor, Fixed, Comp., 2.4M, 1/2W, ±5%	800993	

Assembly, Reference Drive Amplifier, NAI #500050 (Continued)
Figure 4.7, Page 4.7

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
R816,821	Resistor, Fixed, Comp., 10K, ±10%	800089	R816,821	Resistor, Fixed, Comp., 6.2K, 1/2W, ±5%	800614	
R817,820	Resistor, Fixed, Comp., 4.3K, 1/2W, ±5%	800621	R817,820	Resistor, Fixed, Comp., 8.2K, 1/2W, ±5%	800626	
R838,847, 850	Resistor, Fixed, Dep. Carb., 120Ω, 1/4W, ±1%	802250	R838,847 850	Resistor, Fixed, Dep. Carb., 40Ω, 1/4W, ±1%	802862	



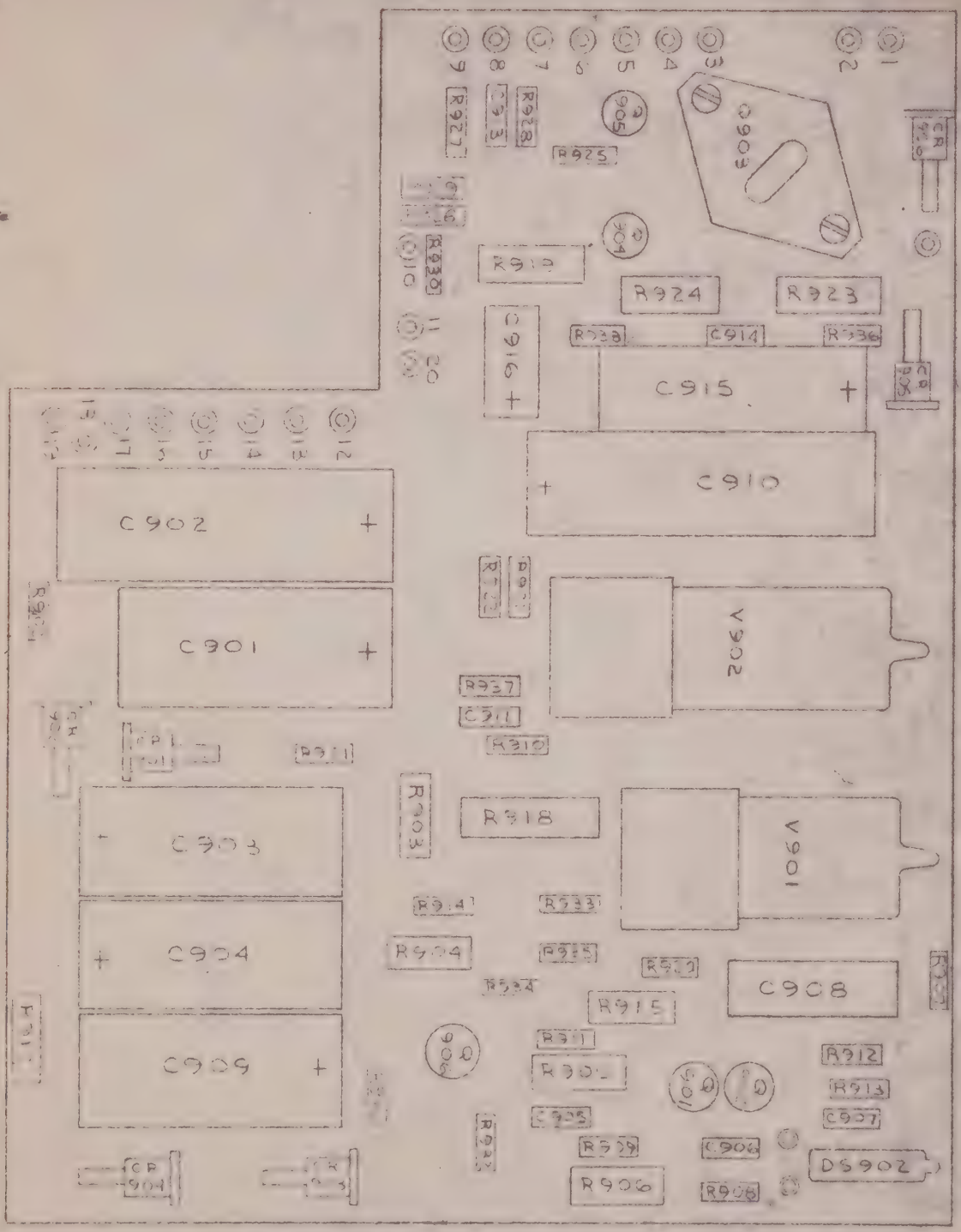
REFERENCE DRIVE AMPLIFIER ASSEMBLY

500050

Figure 4.7

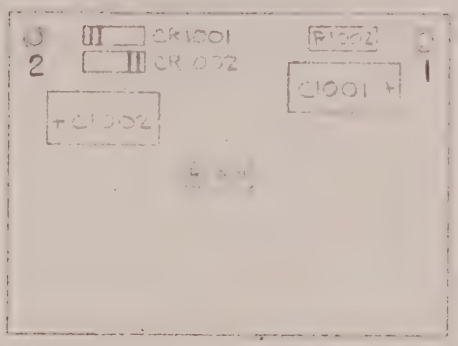
OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
Assembly, Power Supply Board Figure 4.8, Pages 4.30, 4.31, 4.32		500083				
Q906	Transistor, 2N495	802498	Q906	Transistor, 2N697	802107	
R939**	Resistor, Fixed, 1.8K, 1/2W, ±5%	800858	R938**	Resistor, Fixed, Comp., 1.8K, 1/2W, ±5%	800858	Circuit Ref.
R907	Resistor, Fixed, Comp., 270K, 1/2W, ±10%	800059	R907	Resistor, Fixed, 220K, 1/2W, ±10%	800058	
CR903, CR904	Diode, 1N2071	800986	CR903, CR904	Diode, 1N2071 or SR777	800986	
Assembly, Meter Board, Figure 4.9, Page 4.34		500181				
R1002	Resistor, Fixed, Comp., 820Ω, 1/2W, ±10%	800082	R1002	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R1004	Resistor, Fixed, Comp., 2.2K, 1/2W, ±10%					Deleted

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y.
OVerlook 1-8600



POWER SUPPLY TERMINAL BOARD ASSY.
500083

Figure 4.8

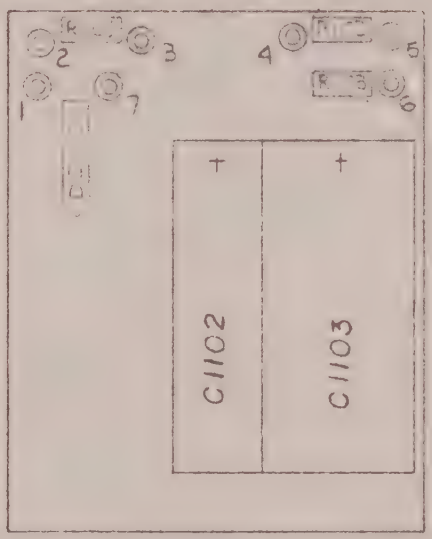


METERBOARD ASSEMBLY

500181

Figure 4.9

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
Assembly, Signal Decoupling Board Figure 4.10, Page 4.36		500177				
			D51101	Lamp, Neon, NE76	801523	Added
C1101	Capacitor, Fixed, 40uf, 150V	800983				Deleted
R1101	Resistor, Fixed, Comp., 4.7K, 1/2W, ±10%	800847	R1101	Resistor, Fixed, Comp., 220K, 1/2W, ±5%	800977	
R1103	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	R1103	Resistor, Fixed, Comp., 20K, 1/2W, ±5%	800521	



SIG. DE-COUPLING BOARD ASSY.
500177

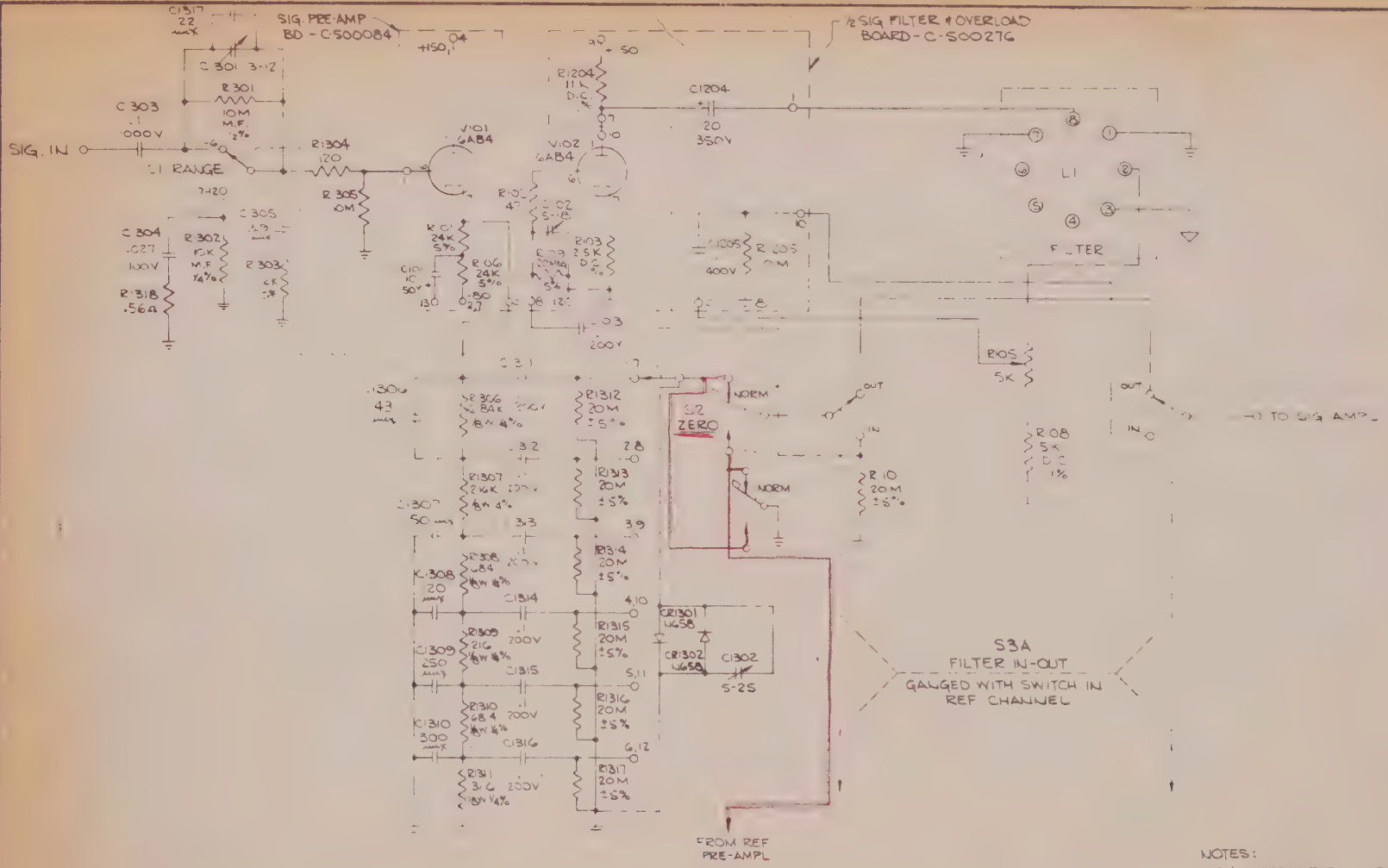
Figure 4.10

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
Assembly, Signal Filter and Overload, Figure 4.11, Page 4.38		500276				
C1201, 1202	Capacitor, Fixed, 22uf, 400V, ±20%	801064	C1201, 1202	Capacitor, Fixed, .22uf 400V, ±10%	800021	
R1202	Resistor, Fixed, Comp., 91K, 1/2W, ±5%	802142	R1202	Resistor, Fixed, Comp., 150K, 1/2W, ±5%	800856	
R1204	Resistor, Fixed, Dep., Carb., 10K, 1/2W, ±1%	801481	R1204	Resistor, Fixed, Dep. Carb., 11K, 1/2W, ±1%	801622	

LOOSE COMPONENTS

OLD			NEW			
Circuit Ref	Description	NAI Part No.	Circuit Ref	Description	NAI Part No.	Remarks
C102	Capacitor, Fixed, 22uuf 500V, ±5%	802164				Deleted
R107	Resistor, Fixed, Dep. Carb., 5K, ±1%	801166				Deleted
R108	Resistor, Fixed, Dep. Carb., 7.5K, ±1%	820562	R108	Resistor, Fixed, Dep. Carb., 5K, ±1%	801166	
R110,109	Resistor, Fixed, Comp., 10M, ±5%	801482	R110	Resistor, Fixed, Comp., 10M, ±5%	801482	Deleted R109
			R632	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R643	Resistor, Fixed, Comp., 200Ω, 1/2W, ±5%	801672				Deleted
R608	Resistor, Fixed, Comp., 18K, 1/2W, ±5%	800611				Deleted
C912	Capacitor, 100uf, 25V	800982	C912	Capacitor, 1000uf, 25V	800982	Error
	Page 4.43					
S5	Switch, Toggle, Ref. Hi - Lo	800112	S5	Switch, Toggle, Ref Hi-Lo	201688	

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y.
S21



12

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W. ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.2 FOR D.C. VOLTAGES

SIGNAL PREAMPLIFIER

FIGURE 3.2

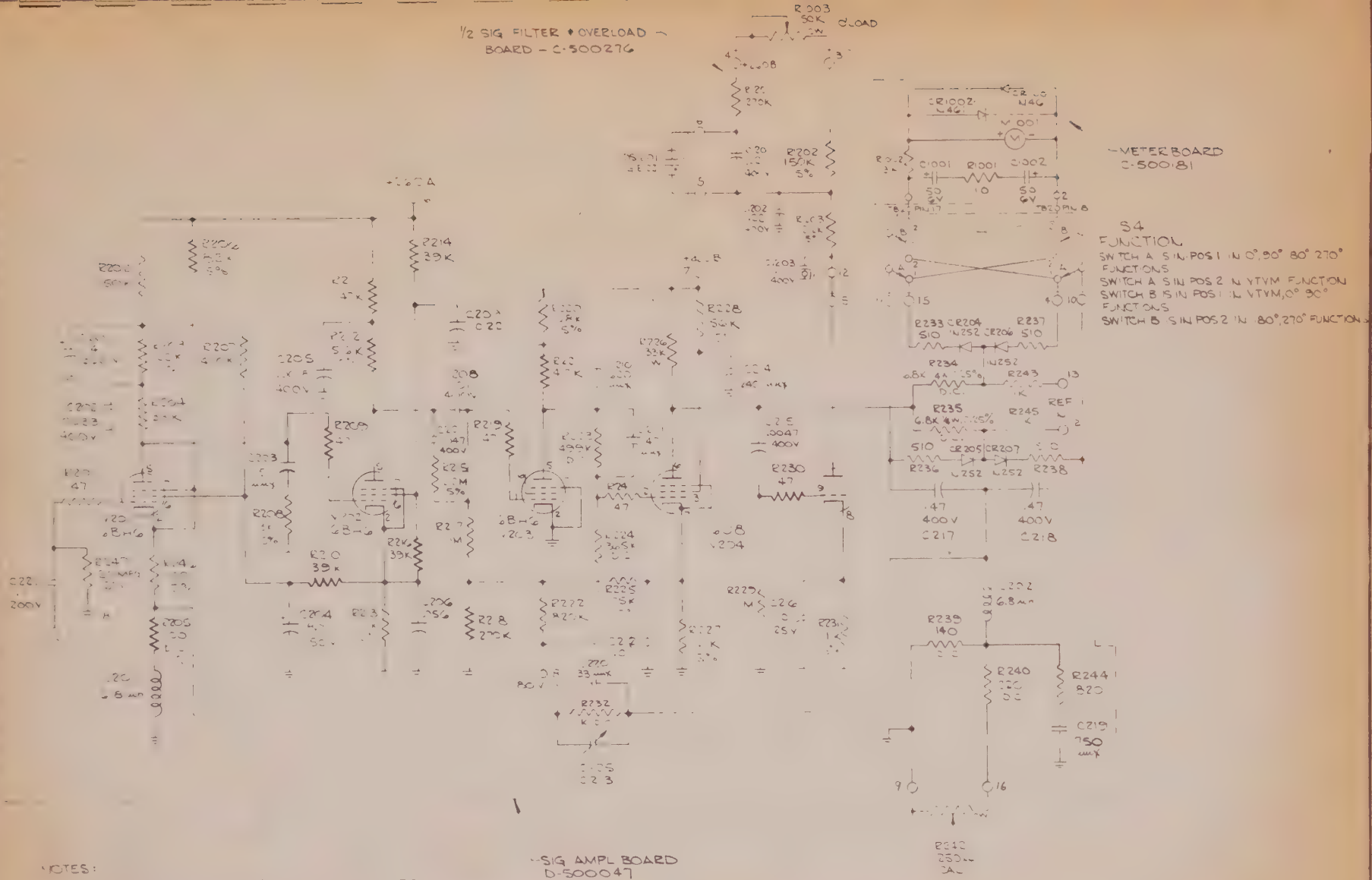
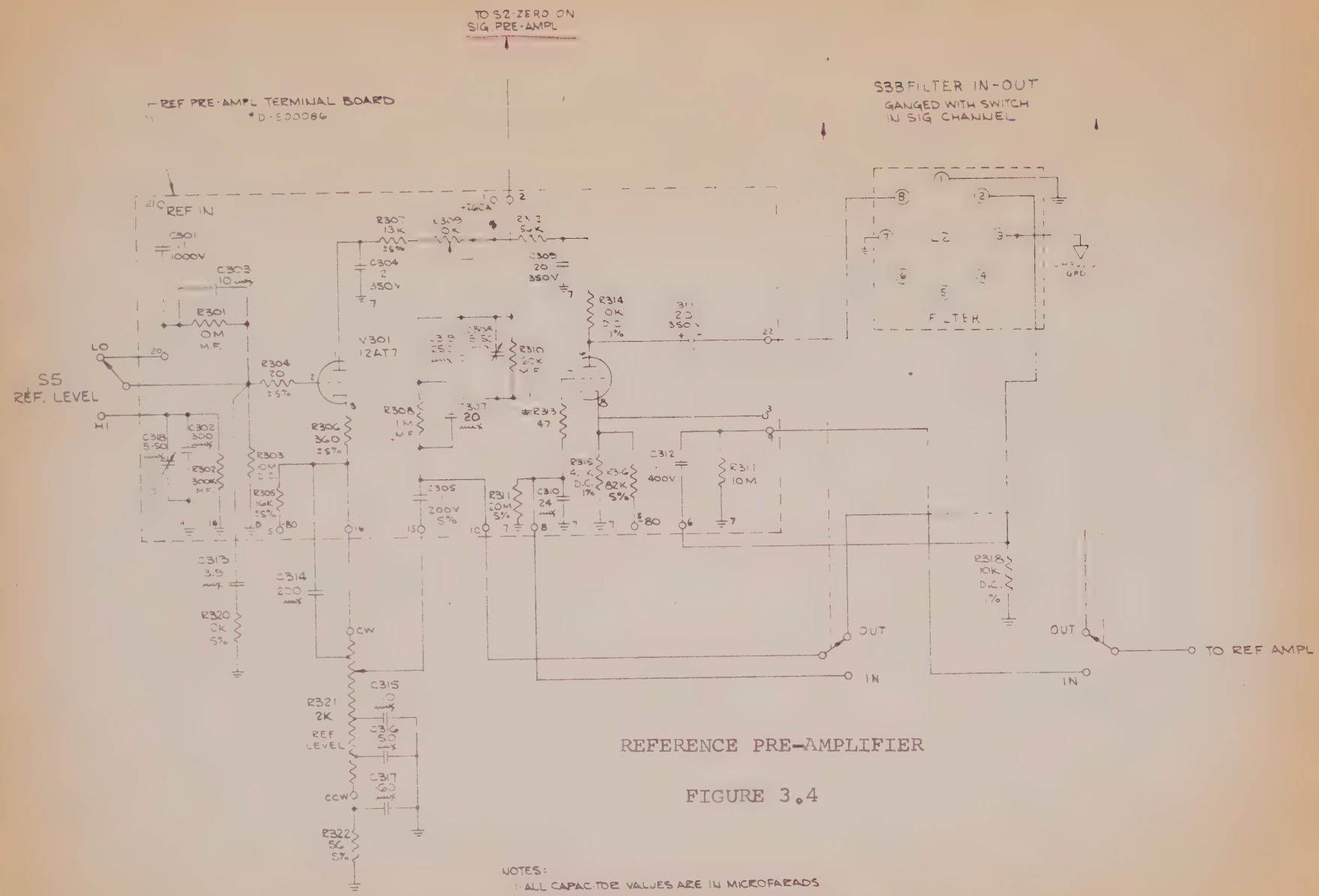

1/2 SIG FILTER + OVERLOAD — BOARD – C-500276
R203 50K
CLOAD
METER BOARD C-500181
S4 FUNCTION
SWITCH A S IN POS 1 IN 0°, 90° 80° 270° FUNCTIONS
SWITCH A S IN POS 2 IN VTVM FUNCTION
SWITCH B IS IN POS 1 IN VTVM, 0° 90° FUNCTIONS
SWITCH B S IN POS 2 IN 180°, 270° FUNCTION
R214 39K
R220 47
R230 47
R239 140
R240 220
R244 820
C219 750 mmf
C217 .47 400V
C218 .47 400V
R238 510
R234 6.8K
R235 6.8K
R243 1K
R245 1K
R236 510
R232 1K
R233 510
R237 510
C1001 50 6V
C1002 50 6V
R1001 10
R1002 3K
M 001
SIG AMPL BOARD D-500047
NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W, ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 52 FOR D.C. VOLTAGES
SIGNAL AMPLIFIER

FIGURE 3.3

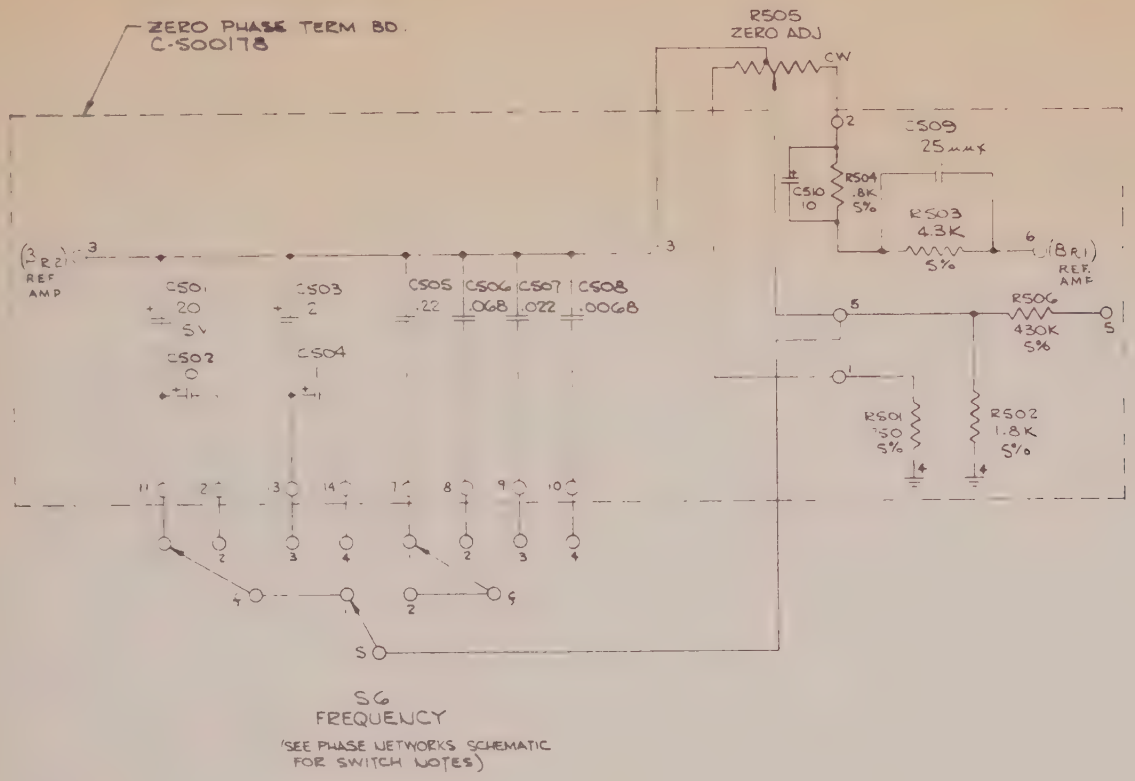


REFERENCE PRE-AMPLIFIER

FIGURE 3.4

NOTES:

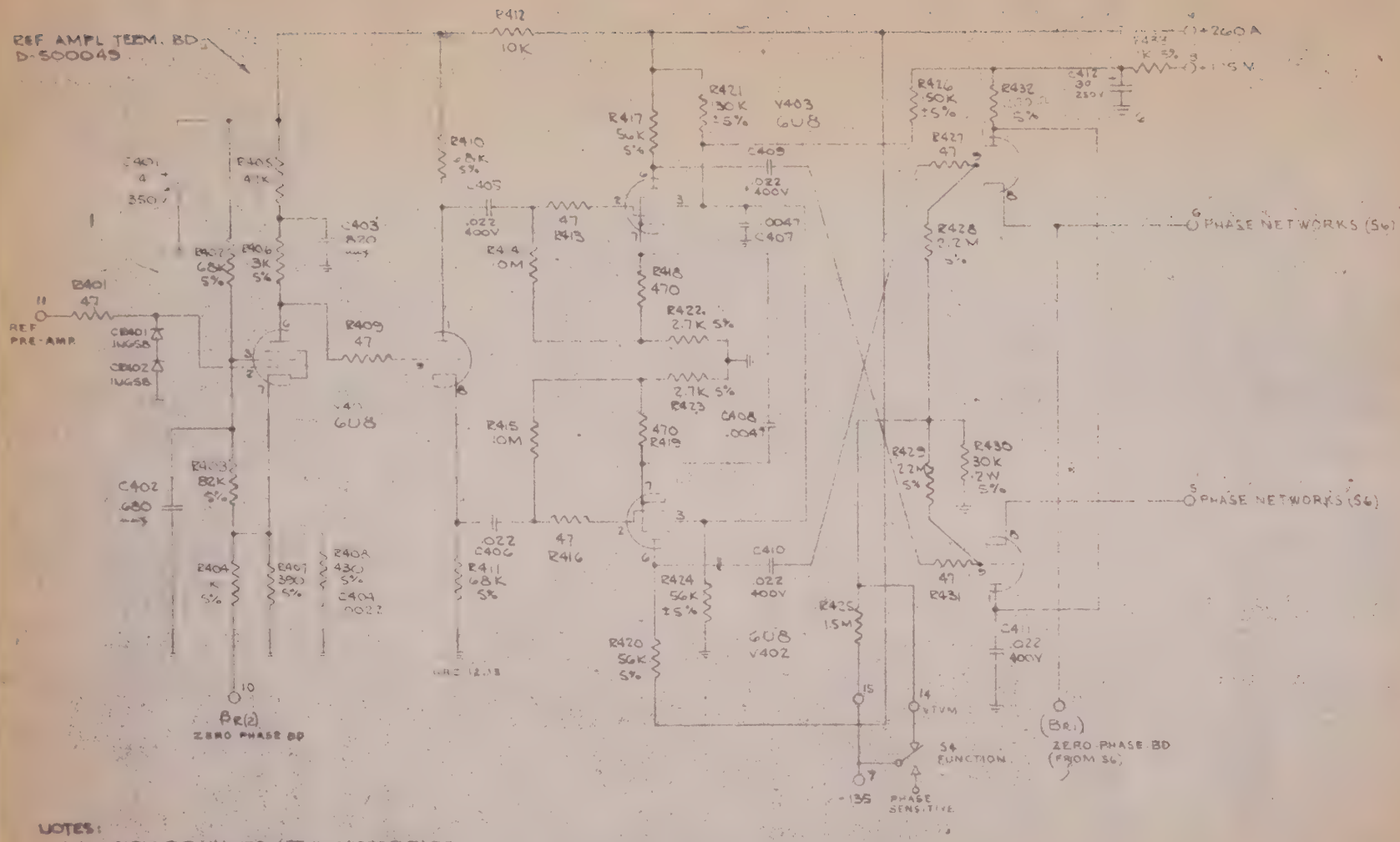
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.2 FOR D.C. VOLTAGES



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10% UNLESS OTHERWISE SPECIFIED

ZERO PHASE

FIGURE 3.7



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.2 FOR DC VOLTAGES

REFERENCE AMPLIFIER

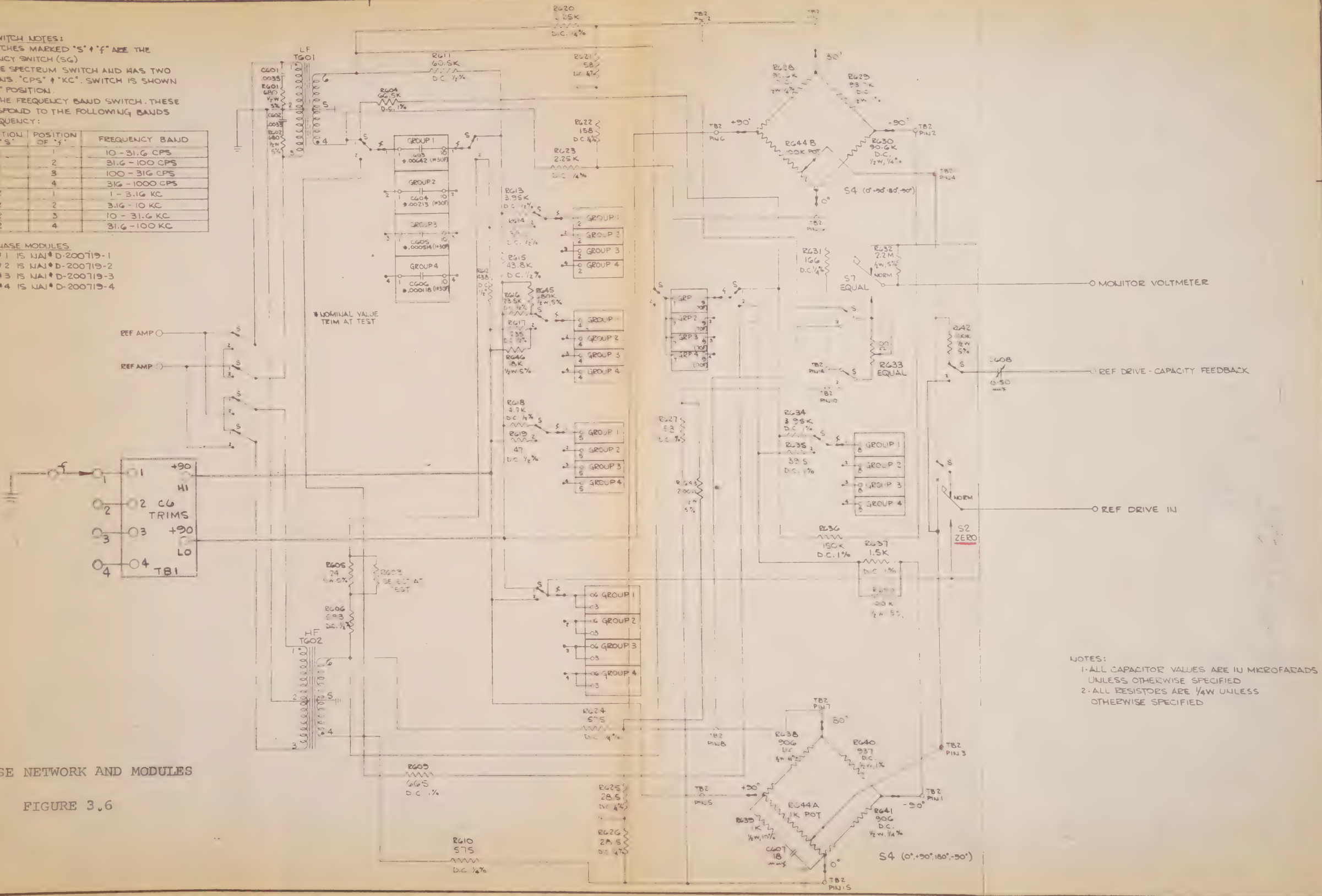
FIGURE 3.5

FREQUENCY SWITCH NOTES:

1. ALL SWITCHES MARKED "S" & "f" ARE THE FREQUENCY SWITCH (SG)
2. "S" IS THE SPECTRUM SWITCH AND HAS TWO POSITIONS, "CPS" & "KC". SWITCH IS SHOWN IN "CPS" POSITION.
3. "f" IS THE FREQUENCY BAND SWITCH. THESE CORRESPOND TO THE FOLLOWING BANDS OF FREQUENCY:

POSITION OF 'S'	POSITION OF 'f'	FREQUENCY BAND
1	1	10 - 31.6 CPS
1	2	31.6 - 100 CPS
1	3	100 - 316 CPS
1	4	316 - 1000 CPS
2	1	1 - 3.16 KC
2	2	3.16 - 10 KC
2	3	10 - 31.6 KC
2	4	31.6 - 100 KC

4. PHASE MODULES
GROUP #1 IS NAI # D-200719-1
GROUP #2 IS NAI # D-200719-2
GROUP #3 IS NAI # D-200719-3
GROUP #4 IS NAI # D-200719-4

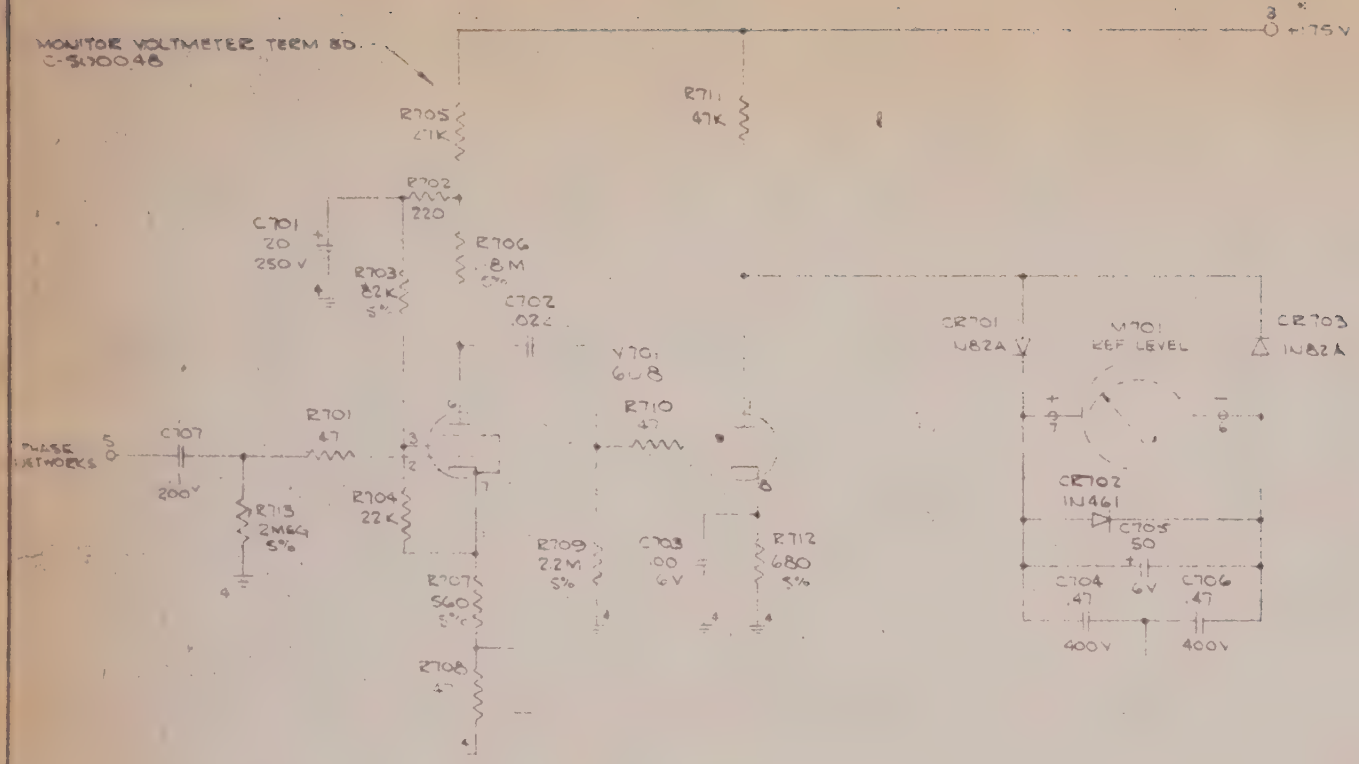


* NOMINAL VALUE TRIM AT TEST

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ¼W UNLESS OTHERWISE SPECIFIED

PHASE NETWORK AND MODULES

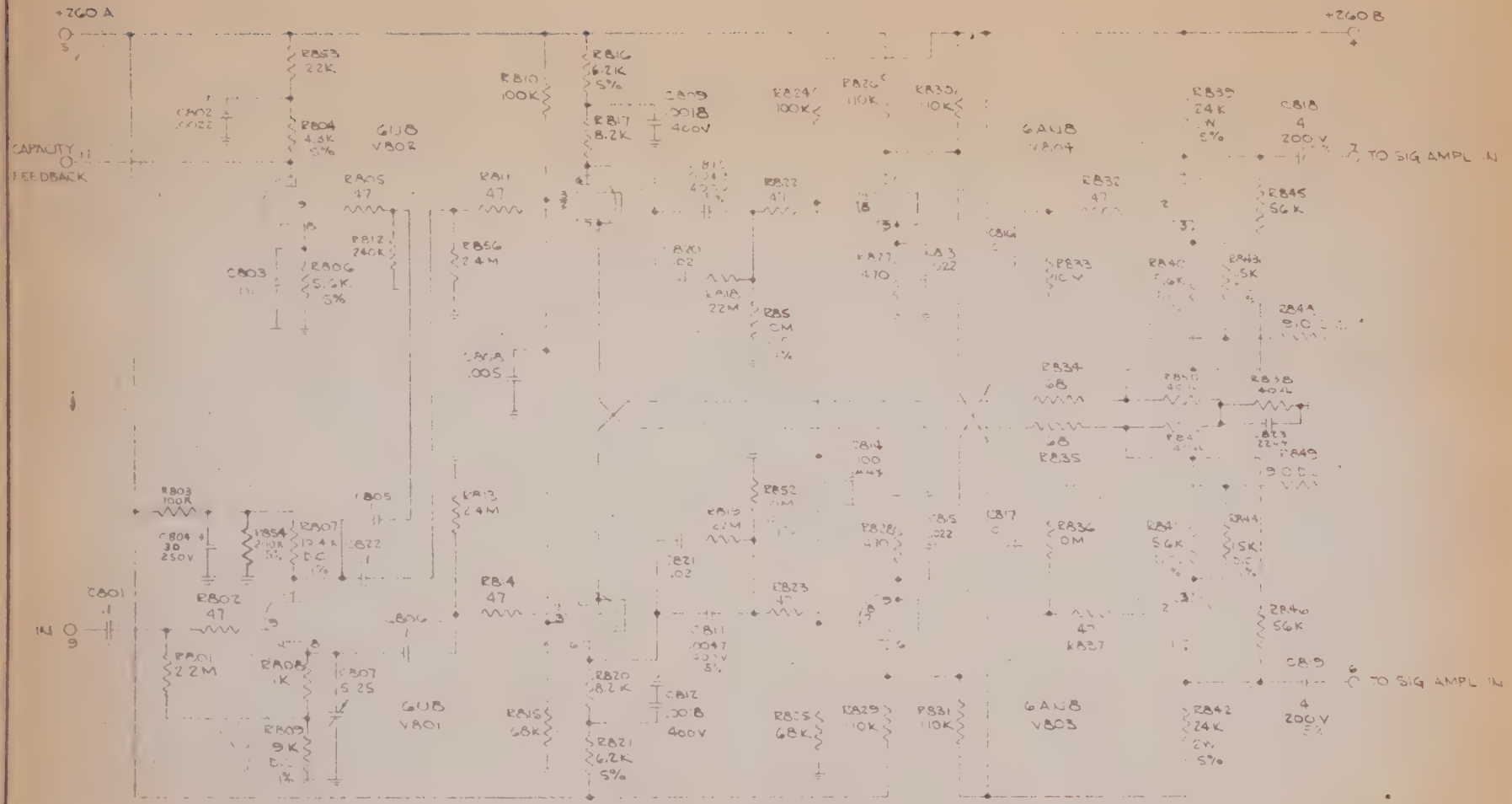
FIGURE 3.6



MONITOR VOLTMETER

FIGURE 3.9

1. ALL CAPACITOR VALUES ARE IN MFD UNLESS OTHERWISE SPECIFIED.
2. ALL RESISTORS ARE 1/2 W 10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.2 FOR D.C. VOLTAGES

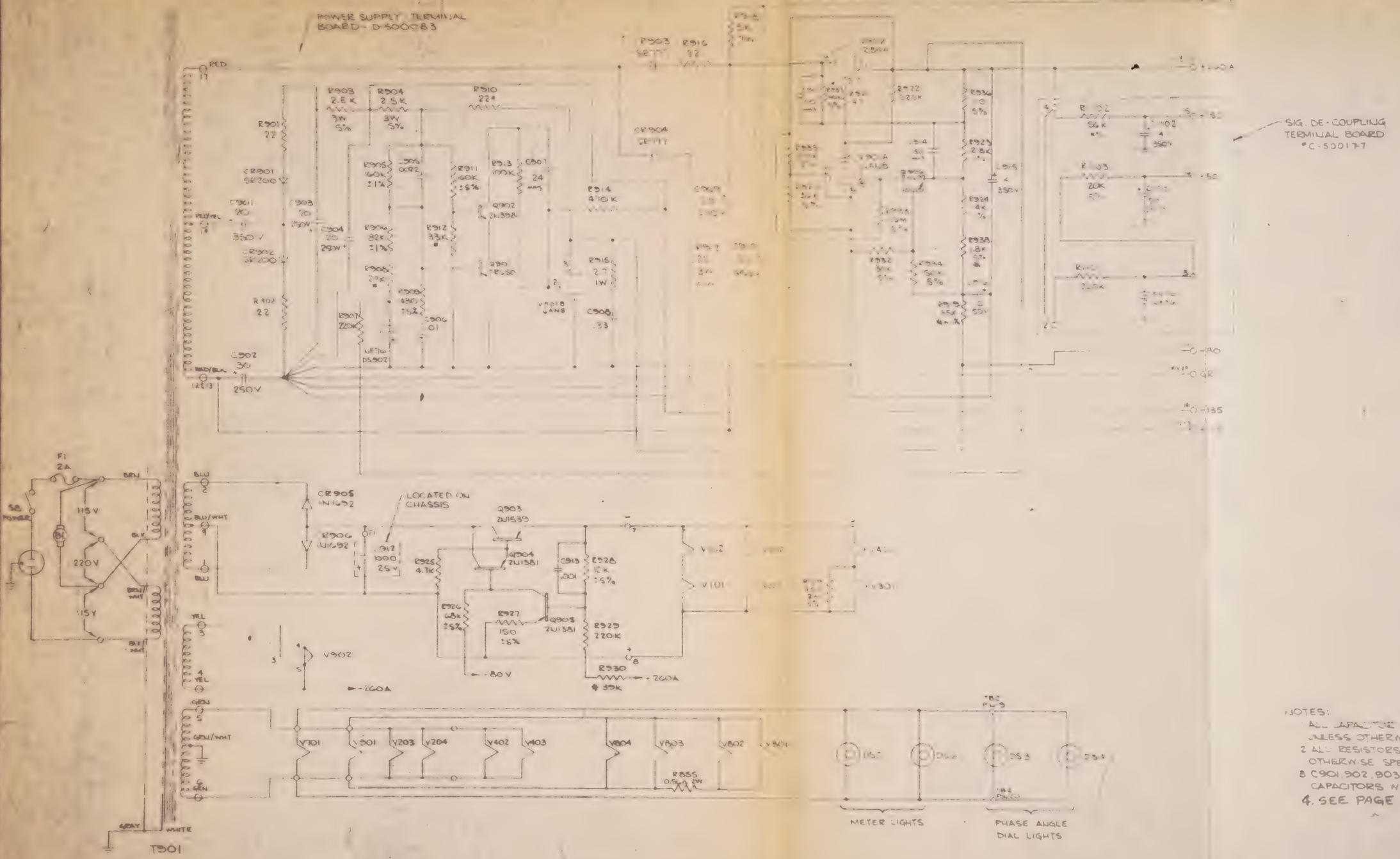


NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED
3. GRD PIN NO'S 1, 8 & 10
4. SEE PAGE 5.2 FOR D.C. VOLTAGES

L REF DRIVE TERM BD D-500050

REFERENCE DRIVER AMPLIFIER

FIGURE 3.10



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W. ±10% UNLESS OTHERWISE SPECIFIED
3. C901, 902, 903, 909 & 912 ARE USED AS INPUT CAPACITORS WITH SILICON RECTIFIER
4. SEE PAGE 5.2 FOR D.C. VOLTAGES

POWER SUPPLY

FIGURE 3.11

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

Shipping

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

SALES REPRESENTATIVES

ALABAMA
FACT-TRONICS
Huntsville: 205-539-7193

ARIZONA
MEASUREMENT CONSULTANTS
Phoenix: 602-264-7709

CALIFORNIA
INSTRUMENT SPECIALISTS, INC.
Glendale: 213-245-9404
San Diego: 714-232-2017
Santa Clara: 408-244-1505

CONNECTICUT
INSTRUMENT REPRESENTATIVES, INC.
Glastonbury: 203-633-0777

FLORIDA
FACT-TRONICS
Casselberry: 305-838-5607

ILLINOIS
PAT LIND ELECTRONICS CO.
Chicago: 312-774-1246

INDIANA
PAT LIND ELECTRONICS CO.
Indianapolis: Enterprise 7711

KANSAS
TECHNICAL REPRESENTATIVES, INC.
Olathe: 913-782-3775
Wichita: 316-682-4140

MARYLAND
RON DAVIES ASSOCIATES
Silver Spring: 301-593-4900

MASSACHUSETTS
INSTRUMENT REPRESENTATIVES, INC.
Arlington: 617-646-1034

MICHIGAN
WKM ASSOCIATES
Detroit: 313-892-2500

MINNESOTA
PAT LIND ELECTRONICS CO.
Circle Pines: 612-781-6568

MISSOURI
TECHNICAL REPRESENTATIVES, INC.
Hazelwood: 314-521-1000

NEW YORK
LABTRONICS, INC.
Syracuse: 315-454-9314
Buffalo: 716-695-1001
Kingston: 914-338-1604

NORTH ATLANTIC INDUSTRIES, INC.
Plainview: 516-681-8600

OHIO
WKM ASSOCIATES
Cleveland: 216-885-5616
Dayton: 513-434-7500

PENNSYLVANIA
ACROMATIX ASSOCIATES, INC.
Fairview Village: 215-279-0377

WKM ASSOCIATES
Pittsburgh: 412-892-2953

TEXAS
SCIENTIFIC SALES CO.
Richardson: 214-231-6541
Houston: 713-781-2711

WASHINGTON
INSTRUMENT SPECIALISTS, INC.
Seattle: 206-767-4260

WISCONSIN
PAT LIND ELECTRONICS CO.
Milwaukee: Enterprise 1611

FOREIGN SALES

Australia
RONALD J. T. PAYNE PTY. LTD.
Richmond, Victoria: 42-1416

Belgium
C. N. ROOD, S.A.
Brussels: 02-35.54.79

Canada
ELECTROMECHANICAL PRODUCTS
Agincourt, Ontario: 416-293-7011

Denmark*
TECHNITRON, A.S.
Copenhagen: Palae 2632

France*
TECHNITRON, S.A.
Paris: 527-49.65

Germany*
TECHNITRON, G.m.b.H.
Munich: 557832/592519

Holland
C. N. ROOD, N.V.
Rijswijk: The Hague 98.51.53

Israel
RACOM ELECTRONICS CO. LTD.
Tel-Aviv: 443244

Italy
MOTORDIESEL
La Spezia: 36.232
Milan: 297035
Rome: 341706

Sweden
AJGERS ELEKTRONIK AB
Stockholm: 08/46 42 46
Skalderviken: 0431/20773

Switzerland
NUCLETRON AG
Bern: 031 3 74 51

United Kingdom
AVELEY ELECTRIC, LTD.
South Ockendon: 3444

All Other Countries
Contact Factory, Cable: NOATLANTIC

*New York Office: Columbia Commerce Corp.: 212-758-2790

9/68

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter, and a power factor meter.

Copyright 1957, 1966 by North Atlantic Industries, Inc.
All Rights Reserved
Printed in U.S.A.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

TABLE OF CONTENTS

		Page
I.	Introduction	1
II.	General Notes on Grounding Techniques	2
III.	Phase Characteristic	6
	1. Response to Harmonics	
	2. Accurate Phase Measurements	
IV.	Phase Angle Measurement Using Phase Shifter	11
V.	Measurement of In-Phase and Quadrature Components	12
VI.	Measurement of Power Factor and Impedance Angle	12
VII.	Measurement of Impedance	13
VIII.	Applications	15
	1. Precision Ratiometer	15
	2. Transducer Nulling	16
	3. Synchro Bridge Null Detector	17
	4. Magnetic Amplifier and Thyratron Circuit Alignment	18
	5. Carrier Circuits and Amplifier	18
	6. Transformation Ratio	19
	7. Small Angle Measurements	22

I - INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instrument's ability to measure the two basic characteristics of any signal; namely, magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure (1).

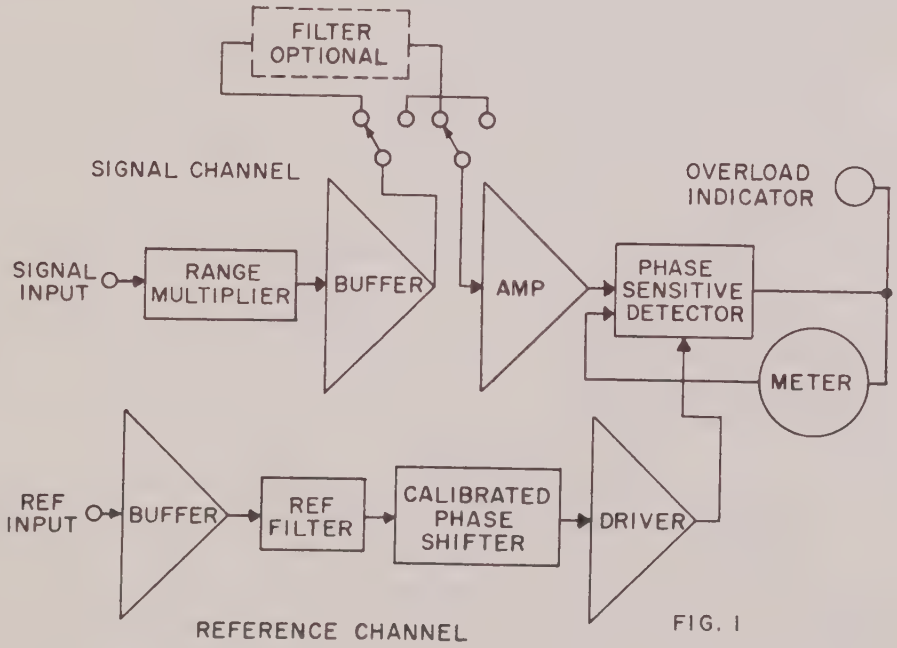


FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an AC signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures (5) and (6).

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II - GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

a) Internal noise
b) Electrostatic pickup
c) Inductive pickup
d) Common ground runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

Electrostatic pickup, frequency a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads one of which is at ground potential. Care must be taken, however, to avoid loading the signal source by the cable capacitance.

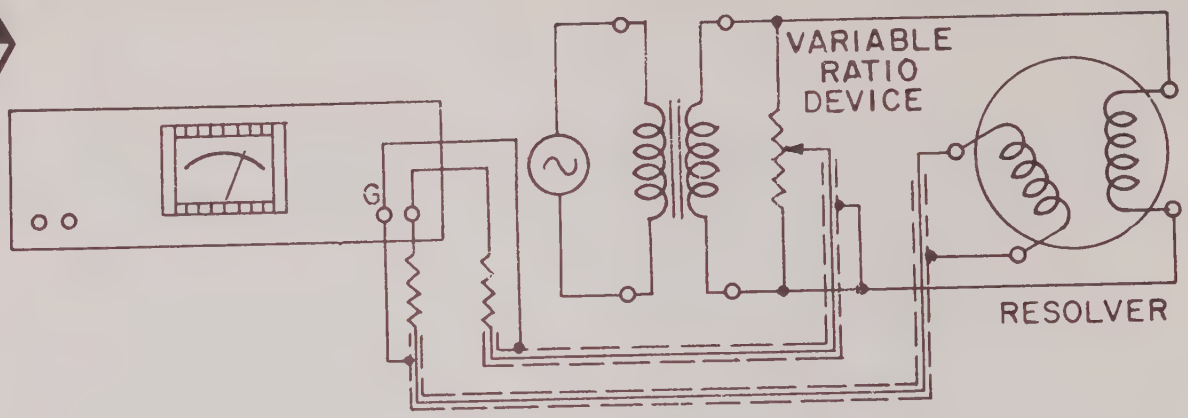
Inductive pickup is generally less often encountered than electrostatic pickup and possibly for that reason, methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that

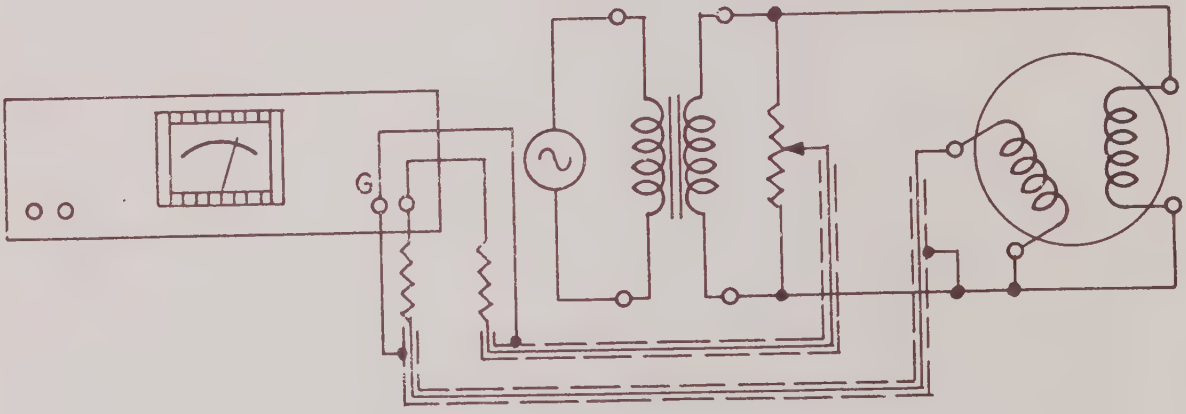
NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

portion of a circuit where a measurement is being made. Figure (2) shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure (2A) is the most advantageous arrangement and is not at all critical to lead runs. Figures (2B) and (2C) both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure (2) can exist due to chassis contact, line cord ground, and reference grounds. All must be considered when setting up the measuring system.

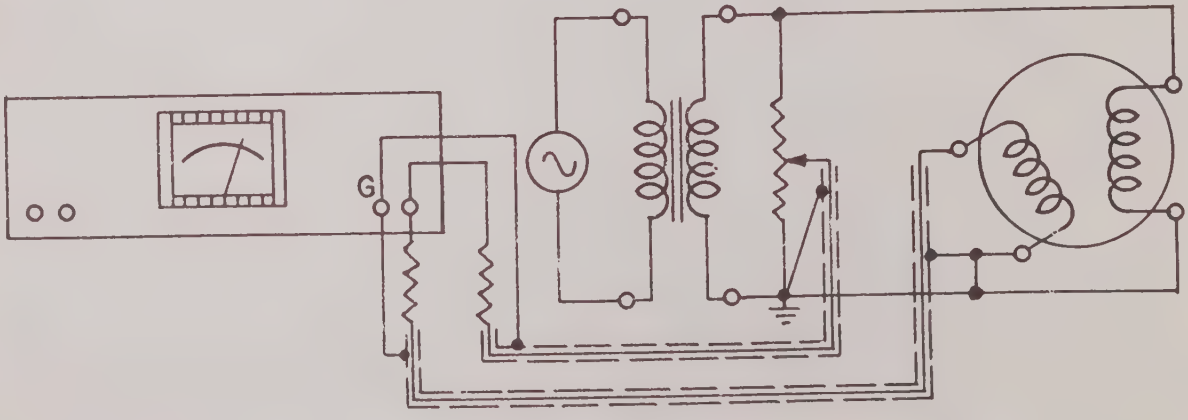
NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Common ground runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure (3) is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure (3) also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

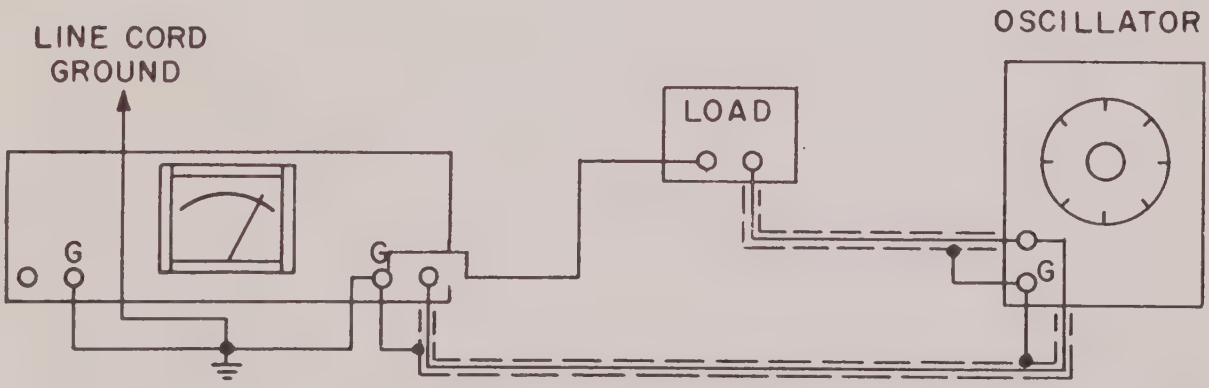


FIG. 3

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

III - PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter
E_{rms} = rms value of the input sine wave
θ = angle between the reference and signal input (Phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

(2) $$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55DB down. Table I shows typical measured responses. The values shown with filters actually are the sum of the colum I data and the filter characteristic.

TABLE I

FUND (400cps)	No Signal Filter 0DB	With Signal Filter 0DB
2nd Har.	-55DB	-55DB
3rd Har.	-9.5DB	-55DB
4th Har.	-55DB	-55DB
5th Har.	-14DB	-55DB

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the setup dhown in Figure (4). The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement than will be a voltage which can be directly translated into degrees using the curves of Figures (5) and (6).

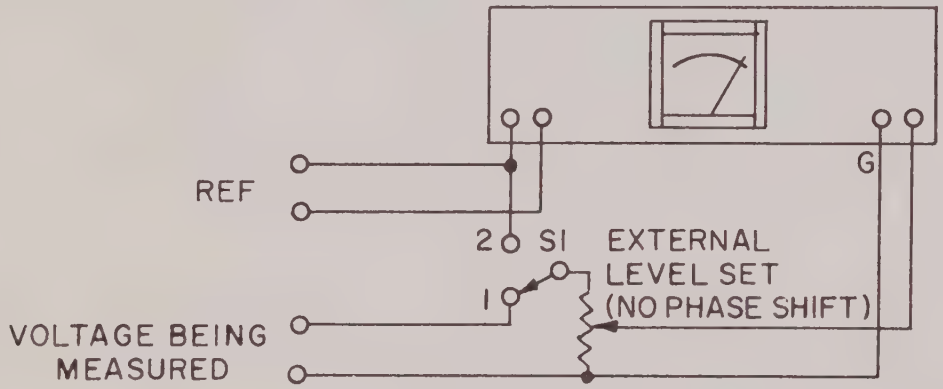


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (NOTE: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.)

3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the θ = 0 deg. point or quadrature null point.

NOTE: FOR MAXIMUM ACCURACY, THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

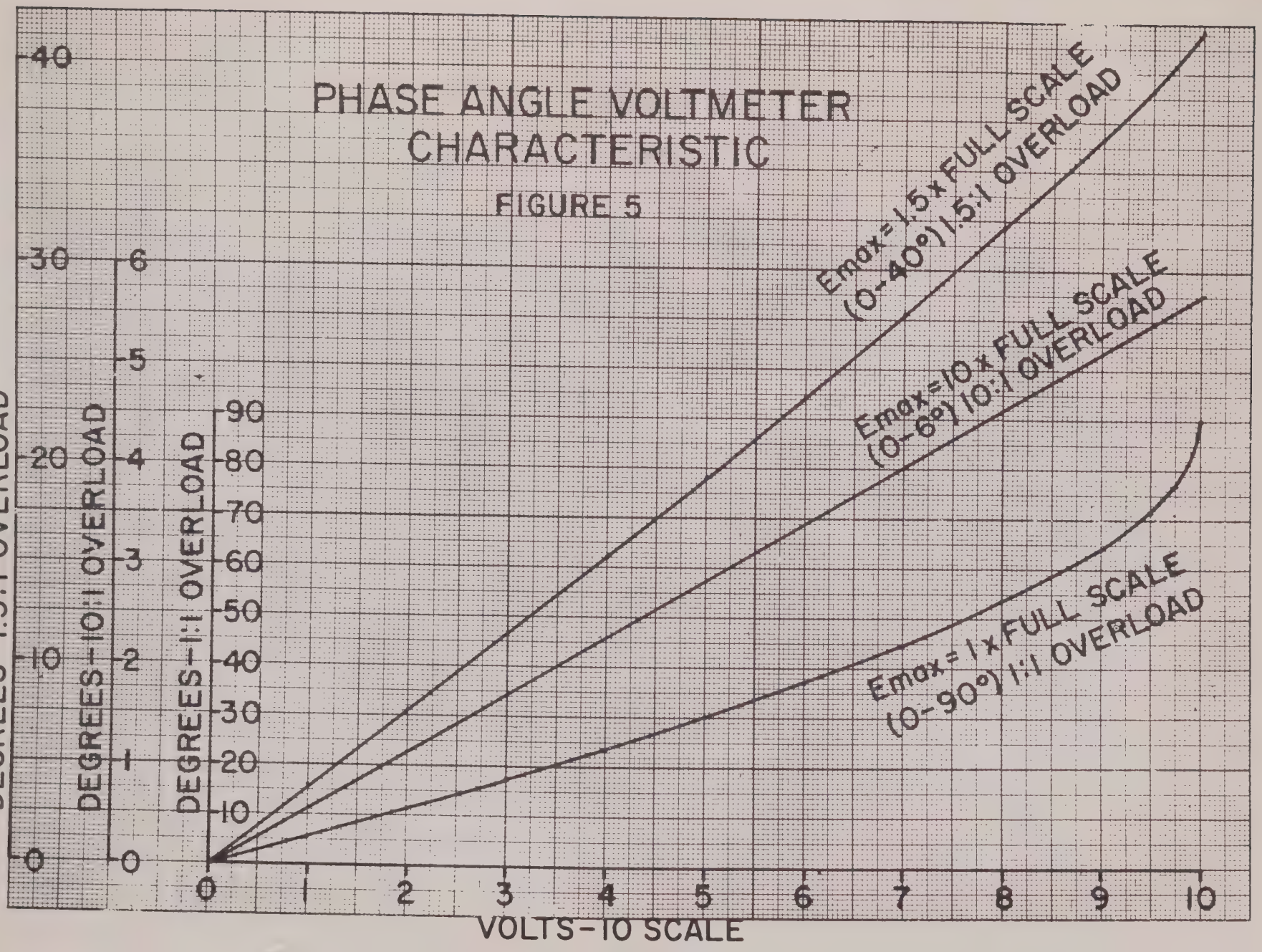
4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the θ = 90 deg. point (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure (5) or (6) to read degrees.

Any full scale range in degrees can be used even down to -6 deg. - 0 - +6 deg, depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4deg. - 0 - +17.4 deg. Table II summarizes typical setups and Figures (5) and (6) show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously, this condition is a function of reference level and for that reason, a level of twice the red line value is recommended when using this technique.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600


PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5 x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10 x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1 x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE

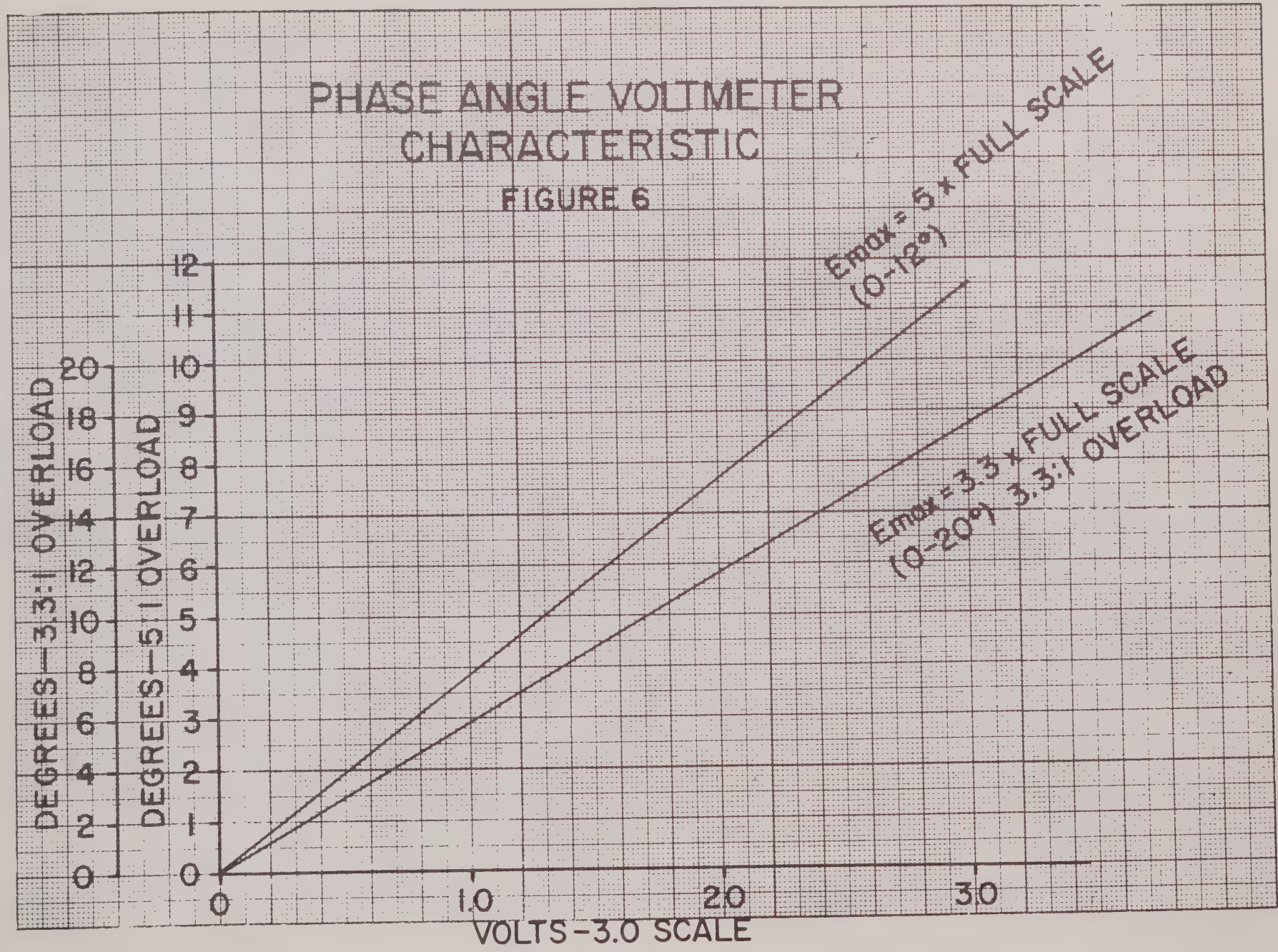

PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES—3.3:1 OVERLOAD
DEGREES—5:1 OVERLOAD
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS-3.0 SCALE

TABLE II

Maximum Voltage	Scale for Measuring Degrees	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	90	2.7 deg.	5
1.0	.3	3.3:1	19.5	0.6	6
1.0	.1	10:1*	5.7	.2*	5
1.5	1.0	1.5:1	41.8	1.3	5
1.5	.3	5:1	11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV - PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built-in, calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees, the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V - MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

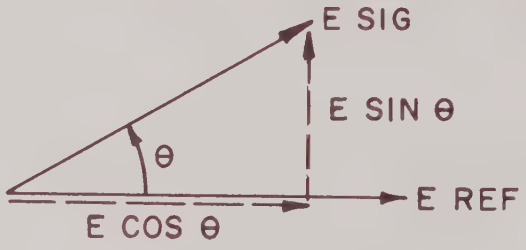


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure (7) as:

In-phase component = E cos θ

Quadrature component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement, the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI - MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This

measurement is conveniently accomplished by means of the set up shown in Figure (8). The angle is measured as previously discussed.

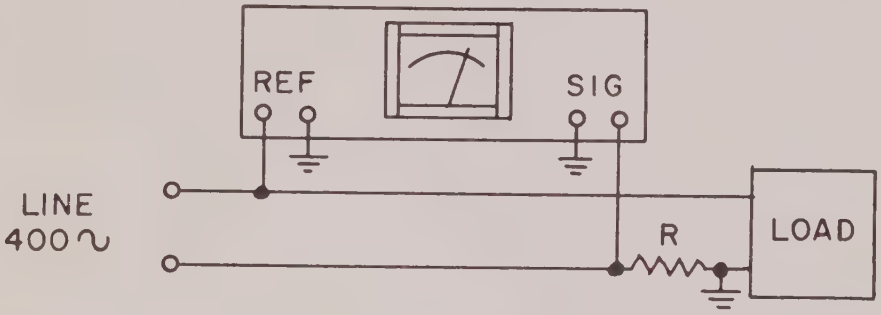


FIG. 8

VII - IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure (9) illustrates the manner in which the measurements can be made.

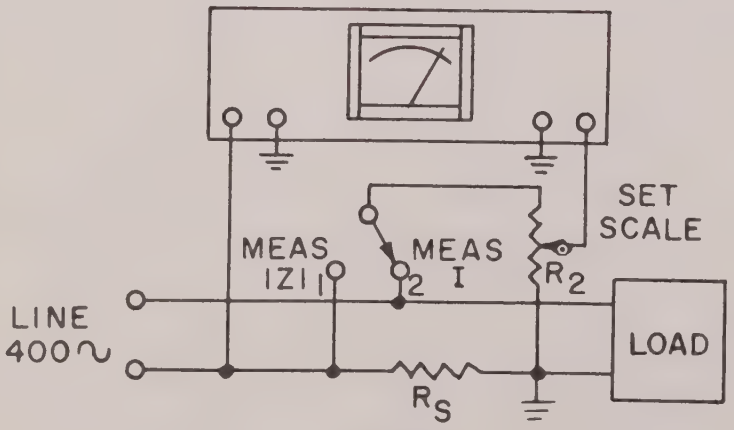


FIG. 9

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Using Table III as a guide, a precision ($\pm$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale voltage on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE:

Load impedance = 470K
Rs = 1K
E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1V equals	Current Factor
10K	10K	1/volts
1K	1K	1/volts
100Ω	100Ω	1/volts
10Ω	10Ω	1/volts
1Ω	1Ω	1/volts

Measurement of AC Resistance and Reactance

By using the circuit of Figure (9) the real and imaginary components of the impedance can also be measured directly by using the current as a reference and measuring the in-phase and quadrature of the signal measured with the switch in position 2. The in-phase component will be the AC Resistance and the quadrature component will be the reactance with the sign determined as positive for a

right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII - APPLICATIONS

Precision Ratiometer

In many analog computer systems the process of multiplication, division, addition, and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure (10) permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

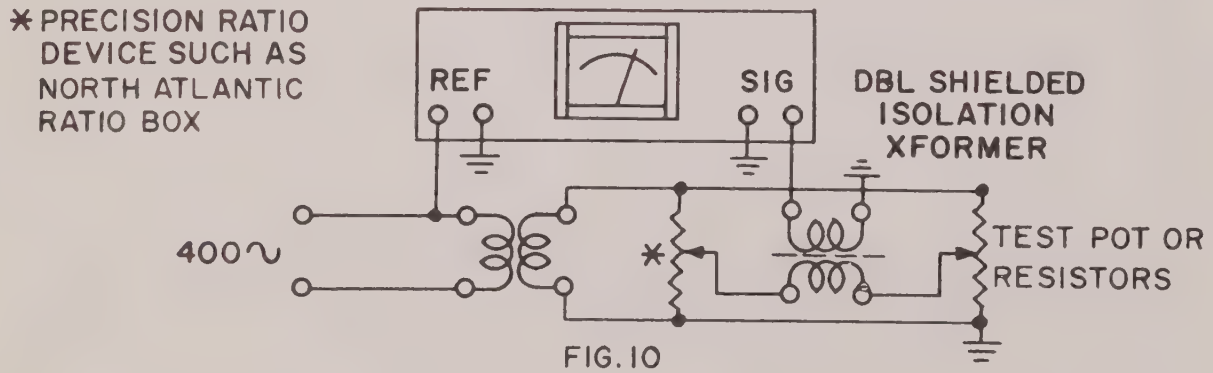


FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance

transformer such as North Atlantic's T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

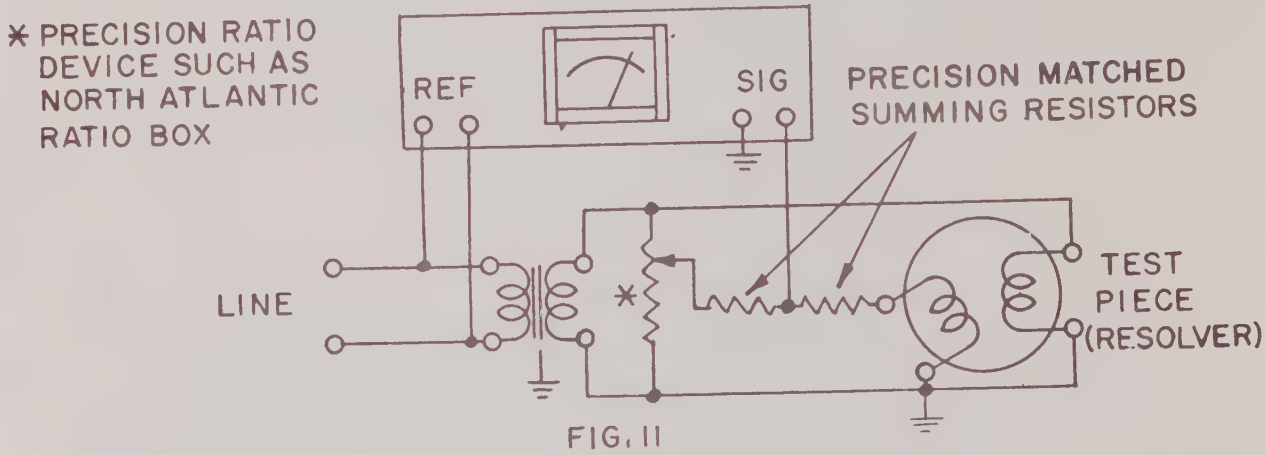


FIG. 11

Transducer Nulling

Applications involving transducers, such as differential transformers or E-Coil pickoffs, are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure (12) shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

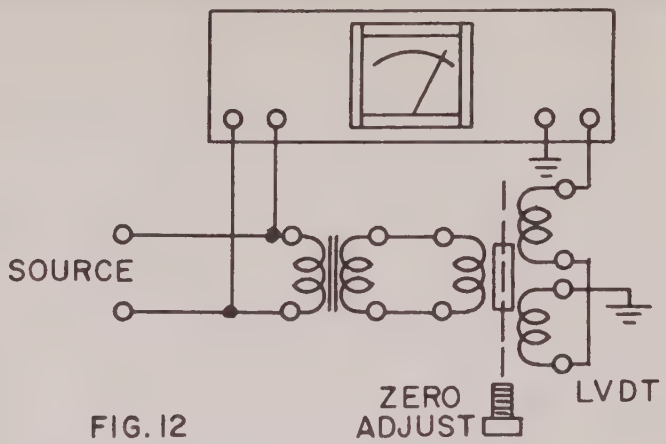


FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure (13) is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible nulls obtainable by conventional instrumentation.

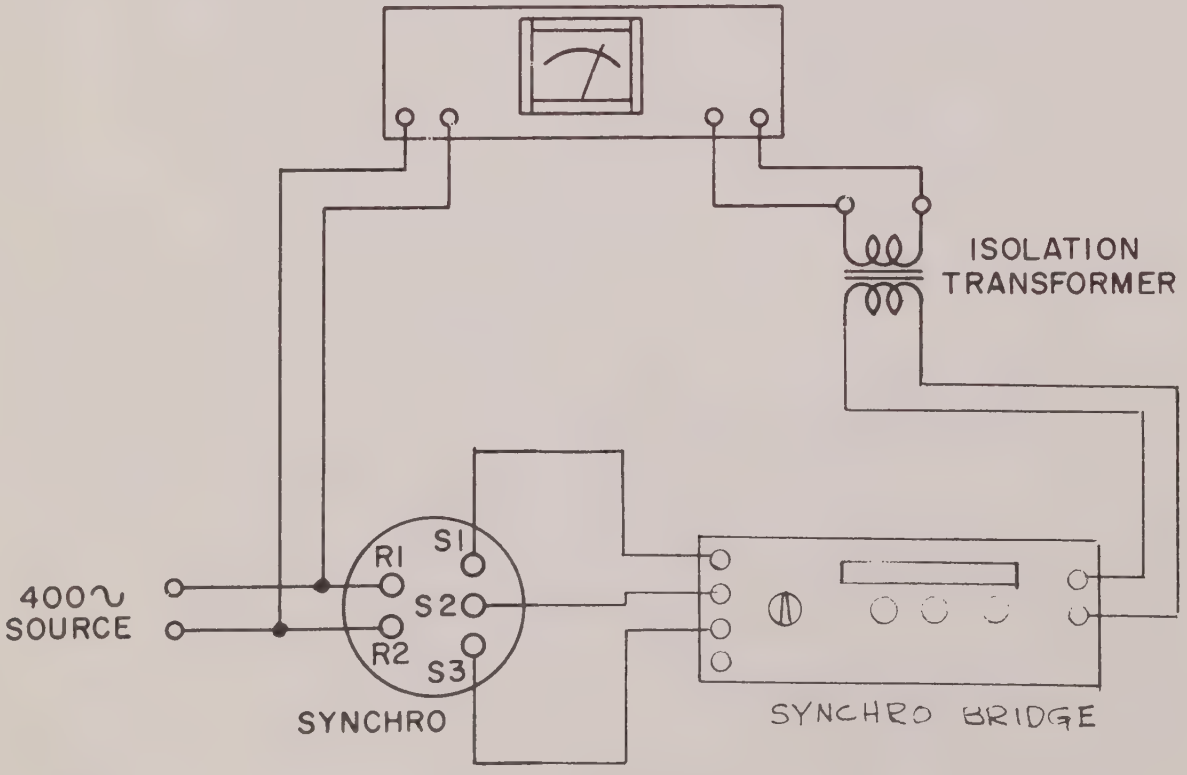


FIG. 13

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped waveforms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure (14) the task of alignment for maximum torque or output is straightforward since the meter reading is equivalent to motor output.

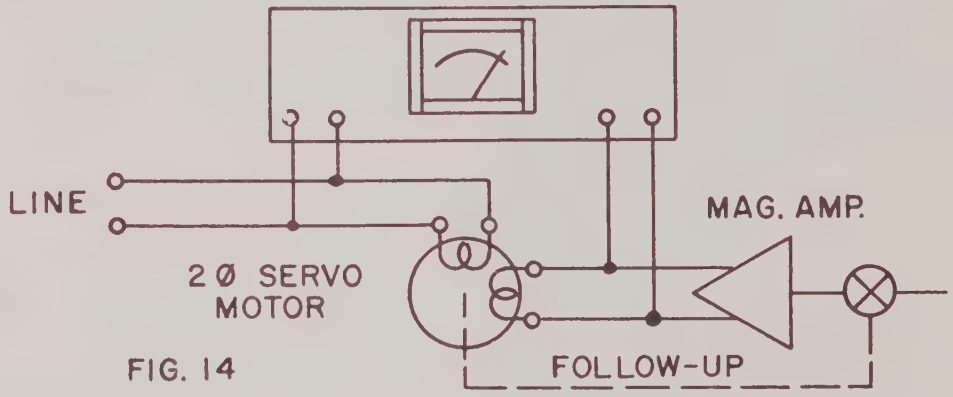


FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc., must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure (15) is a test setup used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

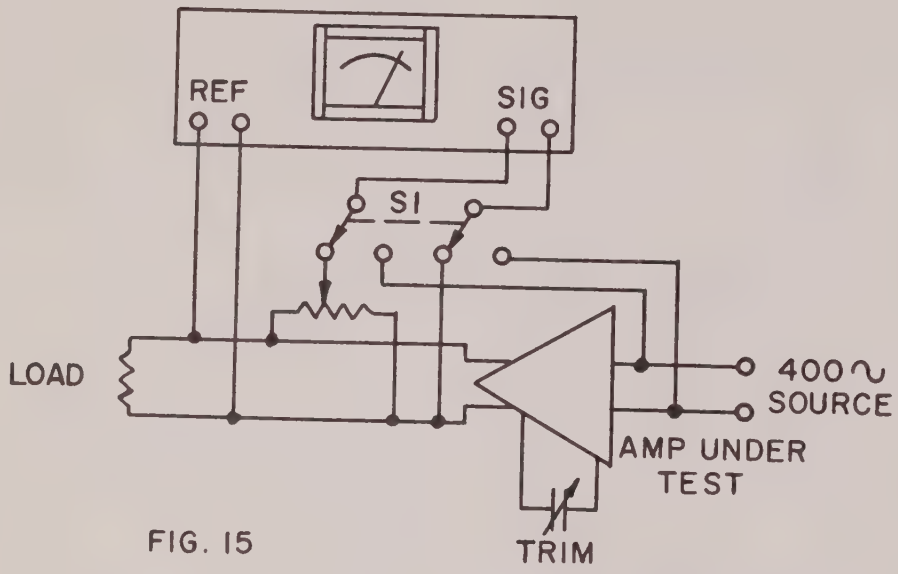


FIG. 15

Transformation Ratio

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure (16a) and (16b).

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

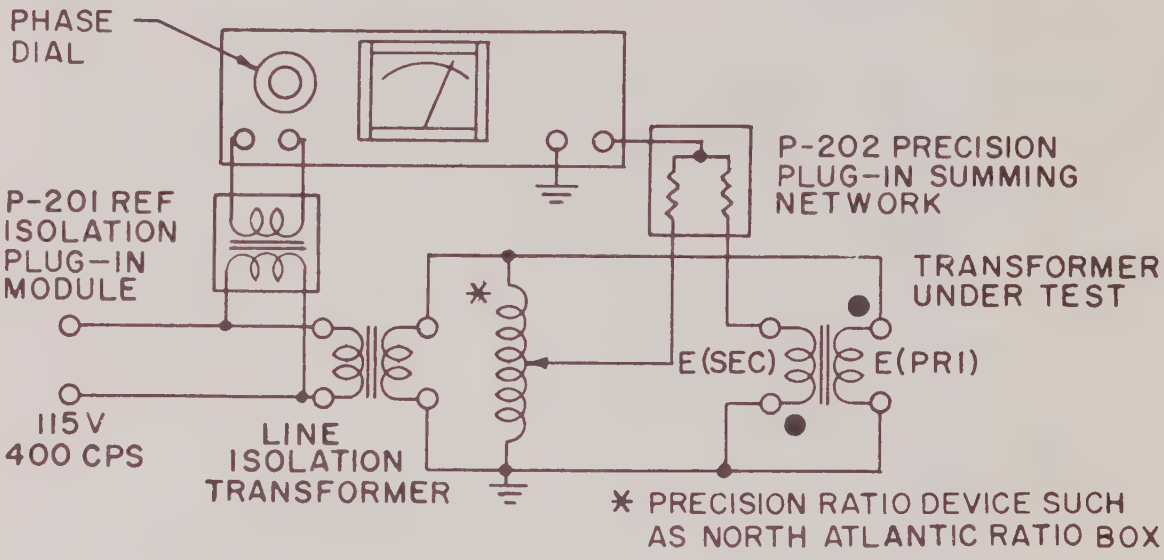


FIGURE 16(a)

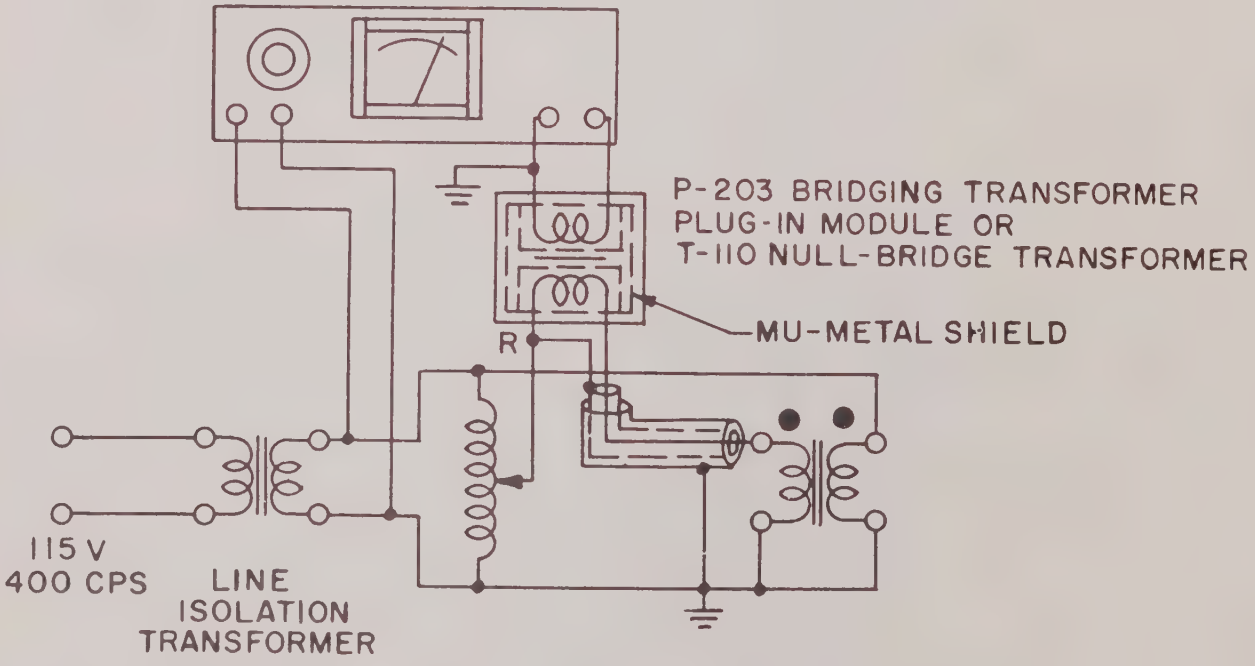


FIGURE 16(b)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

I. SUMMING NETWORK TECHNIQUES

In Figure (16a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test setup a line isolation transformer is utilized so as to avoid grounding one side of theline. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure (16a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure (16b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common-mode rejection and low input capacitance would suffice.

Measurement errors in Figure (16b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the Figure.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Common-mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each setup must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both setups require that the Phase Dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc., This is conveniently done by stepping the ratio device and adjusting the Phase Dial to produce zero output when the Function Selector is in the 90^{o} position. Operation will then be correct when the Function Selector is returned to the 0^{o} position.

Small Angle Measurements

Small angle measurements to better than $.01^{o}$ can also be made using the setups of Figure (16). The process consists of making the in-phase null, described in the foreoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

$$\text{Measured quadrature} = 30.0 \text{ millivolts}$$

$$\text{Secondary voltage} = 30 \text{ volts}$$

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

63133